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Gold Catalysis

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Gold-Catalyzed Regioselective Synthesis of 2- and 3-Alkynyl Furans. **

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Furans are omnipresent in synthetic bioactive compounds, natural products and innovative organic materials (Figure 1).[1] They also give access to equally important tetrahydrofurans via reduction or dihydropyrans via oxidation. It is consequently not surprising that the development of new methods to synthesize and functionalize furans is an area of intense research in modern organic chemistry.[2] In particular, direct metal-catalyzed methods based on C-H functionalization or domino cyclization reactions constitute promising efficient approaches.[3]

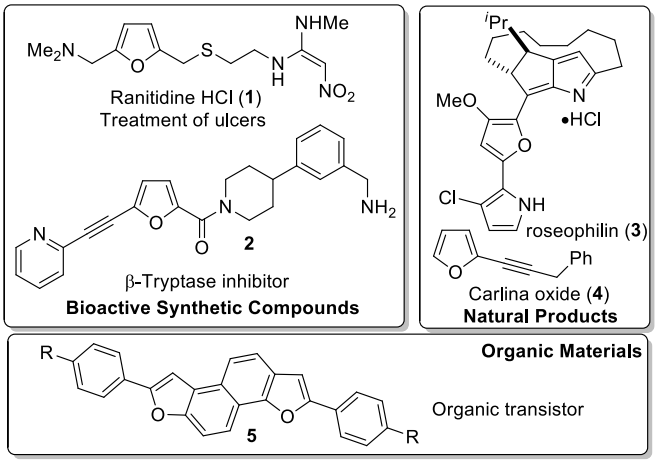

Figure 1. Examples of furans and alkynyl furans in synthetic bioactive compounds, natural products and organic materials.

The efficient synthesis of alkyne-substituted furans would be highly desirable, as these compounds are present in bioactive molecules and natural products (Figure 1). They also constitutes ideal building blocks for the elaboration of more complex scaffolds, due to the versatile chemistry of the triple bond.[4] Recently, efficient direct C-H alkynylation reactions have emerged for the functionalization of a broad range of (hetero)aromatic compounds.[5] In the case of furans, only two examples of direct alkynylation occurring in 45-53% yield have been reported very recently by Su and co-workers.[5m] Alkynylated furans are usually accessed from prefunctionalized heterocycles, with the Sonogashira reaction of halogenated precursors being the most frequently used. New catalytic methods giving a more direct and regioselective access to alkynylated furans need consequently to be developed.

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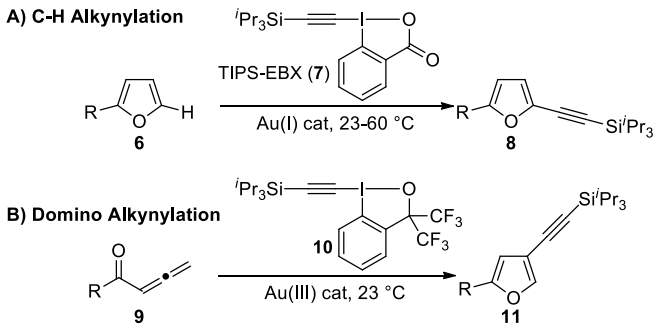
The exceptional properties of gold for the activation of π systems and the functionalization of C-H bonds have been investigated intensively in the last 15 years.[6] Nevertheless, most gold-catalyzed processes were terminated by protonation or halogenation until very recently. In the last five years, important breakthroughs towards more efficient domino processes have been realized using two approaches: the transmetallation of the gold intermediate to another metal[7] and the in situ oxidation to a Au(III) intermediate using a strong oxidant, followed by reductive elimination.[8] Despite this progress, there are currently only two examples of Au-catalyzed alkynylation via in situ oxidation: the C-H functionalization of arenes developed by Nevado and co-workers[5g] and a domino cyclization alkynylation of allenoates to give butenolides introduced by Gouverneur and co-workers.[8d]

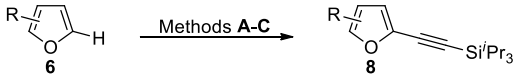
In order to develop more general oxidative electrophilic alkynylation methods, our group has turned towards well-defined hypervalent ethynylbenziodoxolone (EBX) reagents.[9] The unique possibility to tightly modulate the electrophilicity and oxidation potential of these reagents allowed us to develop the Au-catalyzed C-H alkynylation of electron-rich arenes,[9a-e] the metal-free α-alkynylation of carbonyls[9f] and the Pd-catalyzed oxy- and amino-alkynylation of olefins.[9g-h] Herein, we report the first example of direct alkynylation of furans using a Au(I) catalyst and 1-[(tri*iso*propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (TIPS-EBX, **6**). This reaction proceeds at low temperature (23 to 60 °C) and is highly selective for the most electron-rich C2 position of furans. To access C3-alkynylated furans, we then envisaged a domino process based on the well-established Au-catalyzed cyclization of allenic ketones.[6f,10] However, we had shown before that TIPS-EBX (**7**) is not able to intercept Au-C(SP^2) intermediates in domino processes.[9c] Herein, we demonstrate that the modified ethynylbenziodoxole reagent **10** is exceptionally efficient in this domino process, leading to C3-alkynylated furans in high yields at room temperature. The availability of a well-defined reagent for alkynylation in gold-catalyzed domino processes represents a major breakthrough, and is expected to find broad application beyond the synthesis of alkynyl furans.



Scheme 1. Selective Au-catalyzed synthesis of 2- and 3-ethynylated furans via C-H and domino alkynylation.

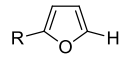
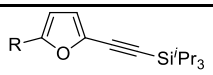
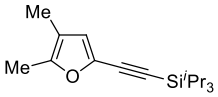
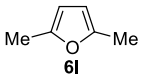
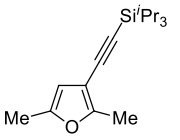
We started our investigations with the C2-alkynylation of 2-hexylfuran (**6a**) as substrate. When this substrate was treated under the standard conditions for thiophene alkynylation (1.2 equivalents TIPS-EBX (**7**),[11] 1.2 equivalents trifluoroacetic acid (TFA) in acetonitrile),[9b] only decomposition of the starting material was observed. This was probably due to the acid sensitivity of furans. In fact, the C2-alkynylation product was obtained in 90% isolated yield in the absence of TFA, allowing us to proceed directly with the examination of the scope of the reaction (Table 1).

Table 1. Scope of the Ethynylation of Furans



6 **8**

A: 1.2 equiv TIPS-EBX (**7**), CH_3CN, 23 °C[a]
B: Neat, 23 °C[b]
C: 1.2 equiv TIPS-EBX (**7**), CH_3CN, 60 °C[c]

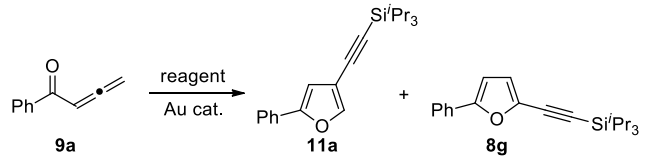
Entry	Substrate	Product	Method	Yield
				
1	R = Hexyl **6a**	**8a**	**A**	90%
2	R = Methyl **6b**	**8b**	**B**	78%
3	R = Ethyl **6c**	**8c**	**B**	79%
4	R = ^{t}Bu **6d**	**8d**	**A**	56%
5	R = CH_2OBn **6e**	**8e**	**C**	55%
6	R = H **6f**	**8f**	**B**	61%
7	R = Phenyl **6g**	**8g**	**C**	68%
8	R = Tolyl **6h**	**8h**	**C**	66%
9	R = 4-MeOPhenyl **6i**	**8i**	**C**	71%
10	R = thiophenyl **6j**	**8j**	**C**	56%
11	 **6k**	 **8k**	**A**	65%
12	 **6l**	 **8l**	**B**	45%

[a] Reaction conditions: 0.40 mmol **6**, 0.48 mmol **7**, 5 mol % AuCl, 0.2 M, rt, 26 h. Isolated yields after column chromatography are given. [b] 1 mL furan **6**, 0.40 mmol **7**, rt, 26 h. [c] As [a] but at 60 °C.

The reaction worked well for 2-alkyl substituted furans (entries 1-5) and furan (**6f**) itself (entry 6). For volatile substrate, it was more convenient to run the reaction in the furan itself as solvent. The alkynylation of 2-aryl furans was slower, but the products could be obtained in 56-71% yield running the reaction at 60 °C (entries 7-10). Finally, disubstituted furans could also be used in the reaction (entries 11 and 12). In case of 2,5-disubstituted furan **6l**, 3-alkynylation product **8l** was obtained in 45% yield (entry 12).

Having developed a C-H functionalization method for the 2-alkynylation of furans, we then turned to the synthesis of the 3-substituted regioisomers based on a domino-cyclization alkynylation process (Table 2). The first results were not promising: a Au(I) catalyst (AuCl) did not promote the cyclization of allene **9a**[12] (entry 1), whereas a Au(III) catalyst ($AuCl_3$) led to cyclization as reported,[10a] but no alkynylation was observed (entry 2). We consequently extended our search to a broad range of other Au(I) and Au(III) catalysts and a promising result was obtained with pyridine-2-carboxylato-gold(III) dichloride (**12**), which gave 24% of the desired 3-alkynylation product **11a** together with 7% of 2-alkynylation (entry 3).[13] In principle, 2-alkynylation could have occurred after premature protonation of the formed gold intermediate. Indeed, furan **8g** was obtained exclusively in 23% yield when catalyst **12** was used with 2-phenyl-furan (**6g**) under the conditions of Table 1. We speculated that a base could prevent protonation of the intermediate Au-C bond and avoid 2-alkynylation. In fact, 3-alkynylation was observed exclusively in presence of bases, with the best result (31%) obtained with sodium carbonate (entries 4-6). However, when using TIPS-EBX (**7**), we were not able to further increase the yield of **11a**, despite extensive optimization of the reaction conditions.

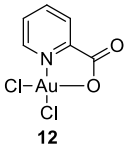
Table 2. Optimization of the Domino Cyclization-Alkynylation.



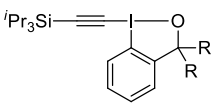
9a **11a** **8g**

entry	catalyst	Equiv reagent	base	solvent	yield **11a/8g**[a]
1	AuCl	1.2 (**7**)	-	CH_3CN	<5%
2	$AuCl_3$	1.2 (**7**)	–	CH_3CN	<5%[b]
3	**12**	1.2 (**7**)	-	CH_3CN	24/7%
4	**12**	1.2 (**7**)	NEt_3	CH_3CN	<5%
5	**12**	1.2 (**7**)	K_2CO_3	CH_3CN	10/0%
6	**12**	1.2 (**7**)	Na_2CO_3	CH_3CN	31/0%
7	**12**	1.2 (**10**)	-	CH_3CN	50/0%[c]
8	**12**	1.2 (**13**)	-	CH_3CN	<5%
9	**12**	1.2 (**14**)	-	CH_3CN	<5%
10	**12**	1.2 (**15**)	-	CH_3CN	<5%
11	**12**	1.2 (**10**)	Na_2CO_3	CH_3CN	33/0%[d]
12	**12**	2.0 (**10**)	Na_2CO_3	CH_3CN	73/0%[d]
13	**12**	2.0 (**10**)	Na_2CO_3	CH_2Cl_2	11/0%[d]
14	**12**	2.0 (**10**)	Na_2CO_3	THF	6/0%[d]
15	**12**	2.0 (**10**)	Na_2CO_3	EtOH	23/0%[d]
16	**12**	2.0 (**10**)	Na_2CO_3	^{i}PrOH	93/0%[d]

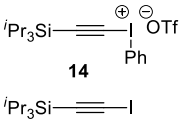
[a] Reaction conditions: 0.1 mmol **9a**, 5 mol % Au cat, 0.02 M, rt, 72 h, isolated yield. [b] Formation of cyclization product **6g** was observed. [c] Furan **6g** was isolated in 14% yield. [d] Yield was determined by GC.



12



10: R = CF_3
13: R = CH_3

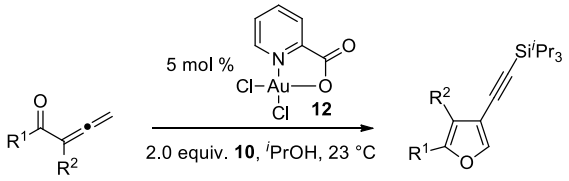


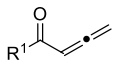
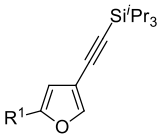
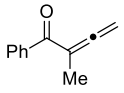
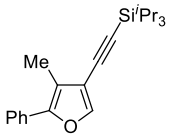
14 **15**

For the domino process to be successful, fine-tuning of the reactivity of the alkynylation reagent is expected to be an essential factor. We consequently decided to examine other hypervalent iodine reagents for the reaction. Indeed, the domino process was more efficient when using bistrifluoromethyl benziodoxole reagent **10**,[11a] which gave 50% **11a** together with 14% of 2-phenyl furan (**6g**), resulting probably from protonation of the putative organogold intermediate (entry 7). The fact that no 2-alkynylation product was obtained in this case is probably due to the lower efficiency of reagent **10** in direct C-H alkynylation.[9d, 14] In contrast, no product was observed with the dimethyl substituted reagent **13** or alkynyl iodonium salt **14**, with a respectively more or less basic oxygen

atom bound to the iodine (entries 8 and 9). On the other hand, no product was observed when alkynyl iodide **15** was used (entry 10). These results further demonstrated that success in this challenging domino process can be achieved only for a very narrow window of electronic density at the iodine atom. In presence of sodium carbonate, the formation of 2-phenyl furan (**6g**) was suppressed, albeit at the cost of the yield of **11a** (entry 11). Fortunately in this case, a larger excess of hypervalent iodine reagent **10** allowed increasing the yield substantially to 73% (entry 12). Finally, reinvestigation of the solvent led to the use of isopropanol, for which the 3-alkynylated product **11a** was obtained in 93% GC yield (entries 13-16). On 0.3 mmol scale, furan **11a** could finally be isolated in 68% yield (Table 3, entry 1).

Table 3. Scope of the Domino Cyclization-Alkynylation

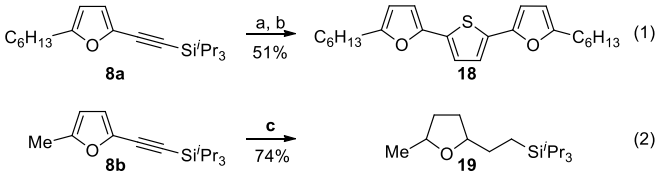


Entry	Substrate	Product	Yield[a]
			
1	R^1 = Phenyl **9a**	**11a**	68%
2	R^1 = 4-MePhenyl **9b**	**11b**	94%
3	R^1 = 3-MePhenyl **9c**	**11c**	95%
4	R^1 = 2-MePhenyl **9d**	**11d**	94%
5	R^1 = 4-MeOPhenyl **9e**	**11e**	83%
6	R^1 = 4-PhPhenyl **9f**	**11f**	53%
7	R^1 = 2-furyl **9g**	**11g**	75%
8	R^1 = hexyl **9h**	**11h**	93%
9	R^1 = ethyl **9i**	**11i**	96%
10	R^1 = cyclohexyl **9j**	**11j**	97%
11	R^1 = benzyl **9k**	**11k**	77%
12	 **16**	 **17**	94%

[a] Reaction conditions: 0.3 mmol **9a**, 5 mol% Au cat **12**, 15 mL *iso*-propanol, rt, 5-72 h, isolated yield after column chromatography are given.

Investigation of the scope of the reaction showed that substitution of the benzene ring by a methyl group led to nearly quantitative yields (94-95%), independently of its position (Table 3, entries 2-4). A para methoxy or a phenyl group were also well tolerated in the reaction (entries 5 and 6), as well as a furyl substituent (entry 7). A current limitation of the method is that electron-withdrawing groups were not tolerated, as in this case Michael addition of the solvent on the allene was observed in isopropanol and decomposition was obtained in other solvents. On the other hand, the reaction was not limited to aromatic substituents, and excellent yields were obtained with both primary (entries 8-9) and a secondary (entry 10) aliphatic substituent. A more sensitive benzyl group was also well tolerated, giving the alkynylation product **11k** in 77% yield (entry 11). Finally, an important preliminary result was obtained for the synthesis of polysubstituted furans: Starting from allene ketone **16**, trisubstituted furan **17** was obtained in 94% yield (entry 12). The synthesis of such product would be very challenging via C-H functionalization, as it would present serious issues of reactivity and regioselectivity.

The obtained silylated alkynyl furan **8a** was easily deprotected to give the corresponding free acetylene. Using a methodology developed previously in our group,[9b] one-pot dimerization and thiophene formation then resulted in the formation of alternating heterocyclic oligomer **18** (Scheme 2, (1)). Heterocyclic oligomers are important in organic materials, but are usually composed of a single class of heterocycles. New properties can be expected to emerge with an easier access to more complex oligomers. On the other hand, hydrogenation gave access to tetrahydrofurans, which are important building blocks for the synthesis of bioactive synthetic and natural products (Scheme 2, (2)).



Scheme 2. Functionalization of alkynyl furans **8a** and **8b**. Reactions conditions: a) TBAF, THF, 0 °C, 1 h, 78%; b) $Cu(OAc)_2$, CH_3CN, 80 °C, 12 h; then $Na_2S•3H_2O$, 80 °C, 24 h, 65%; c) 10 wt % Pd/C, H_2, pentane/EtOH, 12 h, 74%, 5:1 dr.

The results obtained for the C2-alkynylation of furans are in line with our previous work on the alkynylation of heterocycles.[9a-d] In particular, we had shown that AuCl reacts instantaneously with TIPS-EBX (**7**) to form bis(triisopropylsilyl)diyne as major product. This led us to propose a catalytic cycle involving first oxidative addition of Au(I) on the reagent, followed by C-H auration and reductive elimination as one of the most probable mechanisms for this transformation. In this context, the fact that the new domino-alkynylation process is catalyzed by a Au(III) catalyst is mechanistically intriguing. In fact, the only domino-alkynylation process reported so far has been proposed to proceed via a Au(I)-Au(III) catalytic cycle.[8d] To explain our results, an unprecedented electrophilic alkynylation of a Au(III) intermediate has to be postulated. To better understand the unique properties of catalyst **12** in the domino process, several control experiments were done:

1) Product **11a** was obtained in 81% GC yield when the catalyst was formed in situ from $AuCl_3$ and picolinic acid.

2) No product was obtained with $AuCl_3$/pyridine, $AuCl_3$/benzoic acid or $AuCl_3$(pyridine)/benzoic acid as catalyst.

3) Using $AuCl_3$ together with 4-carboxy-pyridine (isonicotinic acid) did also not lead to product formation.

4) Stoichiometric reaction of **12** with **9a** led to the immediate formation of furan **6g**. In contrast to what had been observed with AuCl, no reaction was observed when mixing **12** with benziodoxole **10**.

These experiments demonstrated that a gold(III) picolinic acid complex was required for the domino process, and that the first step in the reaction most probably involved cyclization of the allene. Obviously, further work will be required to better understand the mechanism of the reaction and the exact role of the picolinic ligand.

In summary, we have reported the first selective synthesis of 2- and 3-alkynylated furans based on gold catalysis. An unprecedented Au-catalyzed C-H functionalization with the hypervalent iodine

reagent TIPS-EBX (**7**) was first applied to access 2-ethynylated furans. Using a conceptually different domino cyclization-alkynylation approach, we were able to develop the first Au-catalyzed synthesis of 3-alkynylated furans. Key for success was an unique combination of a Au(III) catalyst and a modified benziodoxole reagent **10**. The clean interception of a Au-C intermediate with a well-defined alkynylation reagent constitute an important breakthrough in the field, and future work will be focused on further applications in Au-catalyzed C-H functionalization and domino processes, as well as to the investigation of the mechanism of the reaction.

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Keywords: Domino Reactions · Alkynes · Furans. · Hypervalent Iodine · Gold Catalysis · C-H Functionalization.

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[8] For a few selected examples, see: a) H. A. Wegner, S. Ahles, M. Neuburger, *Chem. Eur. J.* **2008**, *14*, 11310; b) A. S. K. Hashmi, T. D. Ramamurthi, F. Rominger, *J. Organomet. Chem.* **2009**, *694*, 592; c) G. Z. Zhang, Y. Peng, L. Cui, L. M. Zhang, *Angew. Chem., Int. Ed.* **2009**, *48*, 3112; d) M. N. Hopkinson, J. E. Ross, G. T. Giuffredi, A. D. Gee, V. Gouverneur, *Org. Lett.* **2010**, *12*, 4904; e) A. D. Melhado, W. E. Brenzovich, A. D. Lackner, F. D. Toste, *J. Am. Chem. Soc.* **2010**, *132*, 8885; For reviews, see: f) M. N. Hopkinson, A. D. Gee, V. Gouverneur, *Chem. Eur. J.* **2011**, *17*, 8248; g) P. Garcia, M. Malacria, C. Aubert, V. Gandon, L. Fensterbank, *ChemCatChem* **2010**, *2*, 493; f) H. A. Wegner, M. Auzias, *Angew. Chem., Int. Ed.* **2011**, *50*, 8236.

[9] a) J. P. Brand, J. Charpentier, J. Waser, *Angew. Chem., Int. Ed.* **2009**, *48*, 9346; b) J. P. Brand, J. Waser, *Angew. Chem., Int. Ed.* **2010**, *49*, 7304; c) J. P. Brand, C. Chevalley, J. Waser, *Beilstein J. Org. Chem.* **2011**, *7*, 565; d) J. P. Brand, C. Chevalley, R. Scopelliti, J. Waser, *Chem. Eur. J.* **2012**, *18*, 5655; e) J. P. Brand, J. Waser, *Org. Lett.* **2012**, *14*, 744; f) D. Fernandez Gonzalez, J. P. Brand, J. Waser, *Chem. Eur. J.* **2010**, *16*, 9457; g) S. Nicolai, S. Erard, D. Fernandez Gonzalez, J. Waser, *Org. Lett.* **2010**, *12*, 384; h) S. Nicolai, C. Piemontesi, J. Waser, *Angew. Chem., Int. Ed.* **2011**, *50*, 4680; Review: i) J. P. Brand, D. Fernandez Gonzalez, S. Nicolai, J. Waser, *Chem. Commun.* **2011**, *47*, 102; Use of EBX reagents by other groups: j) Y. Ohta, Y. Tokimizu, S. Oishi, N. Fujii, H. Ohno, *Org. Lett.* **2010**, *12*, 3963; k) H. Shi, L. C. Fang, C. H. Tan, L. L. Shi, W. B. Zhang, C. C. Li, T. P. Luo, Z. Yang, *J. Am. Chem. Soc.* **2011**, *133*, 14944; l) X. S. Liu, Z. T. Wang, X. M. Cheng, C. Z. Li, *J. Am. Chem. Soc.* **2012**, *134*, 14330; m) M. Kamlar, P. Putaj, J. Veselý, *Tetrahedron Lett.* **2013**, *54*, 2097; n) T. Aubineau, J. Cossy, *Chem. Commun.* **2013**, *49*, 3303.

[10] a) A. S. K. Hashmi, L. Schwarz, J. H. Choi, T. M. Frost, *Angew. Chem., Int. Ed.* **2000**, *39*, 228; b) A. W. Sromek, A. V. Kel'in, V. Gevorgyan, *Angew. Chem., Int. Ed.* **2004**, *43*, 2280; c) A. W. Sromek, M. Rubina, V. Gevorgyan, *J. Am. Chem. Soc.* **2005**, *127*, 10500; d) A. S. Dudnik, V. Gevorgyan, *Angew. Chem., Int. Ed.* **2007**, *46*, 5195; e) A. S. Dudnik, A. W. Sromek, M. Rubina, J. T. Kim, A. V. Kel'in, V. Gevorgyan, *J. Am. Chem. Soc.* **2008**, *130*, 1440; f) A. S. Dudnik, Y. Xia, Y. Li, V. Gevorgyan, *J. Am. Chem. Soc.* **2010**, *132*, 7645; g) C. Y. Zhou, P. W. H. Chan, C. M. Che, *Org. Lett.* **2006**, *8*, 325; For palladium-mediated domino processes including arylation, alkenylation and allylation, see: h) S. Ma, J. Zhang, *Chem. Commun.* **2000**, 117; i) S. M. Ma, L. T. Li, *Org. Lett.* **2000**, *2*, 941; j) S. M. Ma, J. L. Zhang, L. H. Lu, *Chem. Eur. J.* **2003**, *9*, 2447.

[11] TIPS-EBX (**7**) is commercially available or can be easily accessed from 2-iodobenzoic acid: a) V. V. Zhdankin, C. J. Kuehl, A. P. Krasutsky, J. T. Bolz, A. J. Simonsen, *J. Org. Chem.* **1996**, *61*, 6547-6551; b) J. P. Brand, J. Waser, *Synthesis* **2012**, *44*, 1155; c) M. J. Bouma, B. Olofsson, *Chem. Eur. J.* **2012**, *18*, 14242.

[12] The allenes required in these studies were synthesized using reported procedures: A. S. K. Hashmi, T. L. Ruppert, T. Knöfel, J. W. Bats, *J. Org. Chem.* **1997**, *62*, 7295.

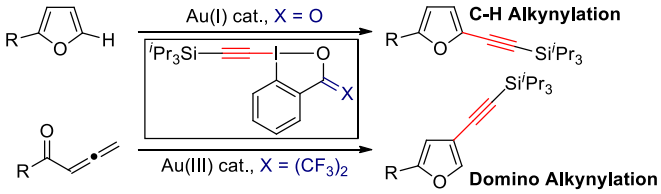
[13] See Supporting Information for a full list of tested catalysts.

[14] Under the optimized reaction conditions (entry 16), no alkynylation of furan **6g** was observed with either reagents **10**, **13** or **14**.

Gold Catalysis

Yifan Li, Jonathan P. Brand and Jérôme Waser _____ **Page – Page**

Gold-Catalyzed Regioselective Synthesis of 2- and 3-Alkynyl Furans.



Chemical Matching: The selective synthesis of either C2 or C3-alkynylated furans using gold catalysis is presented. Direct C-H alkynylation of furans was achieved with C2 selectivity. A domino cyclization-alkynylation process starting from allenes gave C3-alkynylated products. The exact matching of the structure of the gold catalyst and an electrophilic hypervalent iodine reagent was essential for success.

Supporting Information

60 pages

Table of content

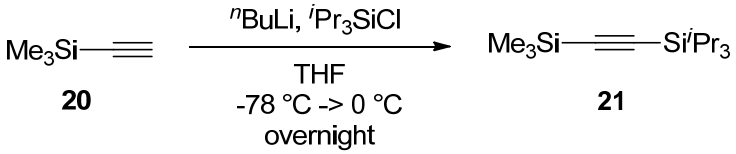
1. General method

All reactions were carried out in oven dried glassware under an atmosphere of nitrogen, unless stated otherwise. For quantitative flash chromatography technical grade solvents were used. For flash chromatography for analysis, HPLC grade solvents from Sigma-Aldrich were used. THF, Et_2O, CH_3CN, toluene, hexane and CH_2Cl_2 were dried by passage over activated alumina under nitrogen atmosphere (H_2O content < 10 ppm, *Karl-Fischer* titration). NEt_3 and pyridine were distilled under nitrogen from KOH. Gold chloride was purchased from Aldrich and kept in desiccator under anhydrous condition (decrease of reactivity has been observed for catalyst if prolonged exposition to air (*ca* 1 month). All chemicals were purchased from Acros, Aldrich, Fluka, VWR, Aplichem or Merck and used as such unless stated otherwise. Chromatographic purification was performed as flash chromatography using Macherey-Nagel silica 40-63, 60 Å, using the solvents indicated as eluent with 0.1-0.5 bar pressure.TLC was performed on Merck silica gel 60 F_{254} TLC glass plates or aluminium plates and visualized with UV light, permanganate stain, CAN stain or Anisaldehyde stain. Melting points were measured on a Büchi B-540 melting point apparatus using open glass capillaries, the data is uncorrected. ^{1}H-NMR spectra were recorded on a Brucker DPX-400 400 MHz spectrometer in chloroform-d, DMSO-d_6 or CD_3OD, all signals are reported in ppm with the internal chloroform signal at 7.26 ppm, the internal DMSO signal at 2.50 ppm or the internal methanol signal at 3.30 ppm as standard. The data is being reported as (s = singlet, d = doublet, t = triplet, q = quadruplet, qi = quintet, m = multiplet or unresolved, br = broad signal, app = apparent, coupling constant(s) in Hz, integration, interpretation).^{13}C-NMR spectra were recorded with ^{1}H-decoupling on a Brucker DPX-400 100 MHz spectrometer in chloroform-d, DMSO-d_6 or CD_3OD, all signals are reported in ppm with the internal chloroform signal at 77.0 ppm, the internal DMSO signal at 39.5 ppm or the internal methanol signal at 49.0 ppm as standard. Infrared spectra were recorded on a JASCO FT-IR B4100 spectrophotometer with an ATR PRO410-S and a ZnSe prisma and are reported as cm^{-1} (w = weak, m = medium, s = strong, br = broad). Gas chromatographic and low resolution mass spectrometric measurements were performed on a Perkin-Elmer Clarus 600 gas chromatographer and mass spectrometer using a Perkin-Elemer Elite fused silica column (length: 30 m, diameter: 0.32 mm) and Helium as carrier gas. High resolution mass spectrometric measurements were performed by the mass spectrometry service of ISIC at the EPFL on a MICROMASS (ESI) Q-TOF Ultima API. HPLC measurement were done on a JASCO HPLC system with an AS2055 Autosampler, a PU 2089 Pump, a UV 2075 detector and a SEDEX 85 (SEDERE) detector using a CHIRALPAK IC column from DAICEL Chemical Industries Ltd. HPLC grade solvents from Sigma-Aldrich were used.

2. Preparation of Reagents

Caution! Even if we never had explosions in our laboratory, all hypervalent iodine reagents are high energy compounds and should be handled with care. Reactions on larger scale especially should be done using adequate personal protection and behind safety shields.

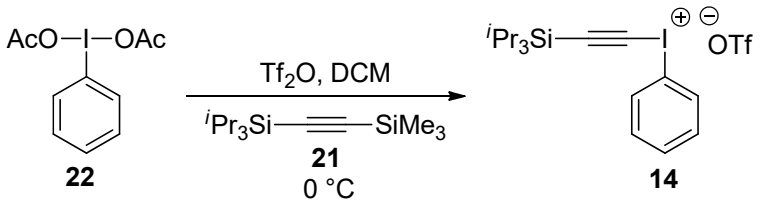
Tri*iso*propylsilyl trimethylsilylacetylene (21)



Following a reported procedure,[1] *n*-butyllithium (2.5 M in hexanes, 12.0 mL, 29.9 mmol, 0.98 equiv) was added dropwise to a stirred solution of ethynyltrimethylsilane (**20**) (3.0 g, 30 mmol, 1.0 equiv) in THF (48 mL) at -78 °C. The mixture was then warmed to 0 °C and stirred for 5 min. The mixture was then cooled back to -78 °C and chlorotri*iso*propylsilane (6.4 mL, 30 mmol, 1.0 equiv) was added dropwise. The mixture was then allowed to warm to room temperature and stirred overnight. A saturated solution of ammonium chloride (40 mL) was added, and the reaction mixture was extracted with diethyl ether (2 x 60 mL). The organic layer was washed with water and brine, then dried over $MgSO_4$, filtered and concentrated under reduced pressure to obtain a colorless liquid which was further purified by Kugelrohr distillation (56-57°C/0.25 mmHg) to yield **21** (7.16 g, 28.0 mmol, 92% yield) as a colorless liquid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 1.08 (m, 21 H, TIPS), 0.18 (s, 9 H, TMS). IR ν 2959 (m), 2944 (m), 2896 (w), 2867 (m), 1464 (w), 1385 (w), 1250 (m), 996 (w), 842 (s), 764 (s), 675 (m), 660 (m). Characterization data of **21** corresponded to the literature values.[1]

Phenyl(tri*iso*propylsilyl)iodonium triflate (14)



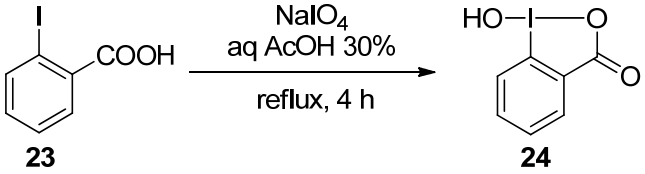
Following a slight modification of the reported procedure,[2] phenyliodonium diacetate (**22**) (2.53 g, 7.85 mmol, 1.00 equiv) was diluted with DCM (7 mL) and the mixture was stirred for 5 minutes. Tf_2O (0.60 mL, 3.9 mmol, 0.50 equiv.) was added dropwise at 0 °C and the resulting yellow mixture was stirred 30 min. (Trimethylsilyl)(tri*iso*propylsilyl)acetylene (**21**) (2.00 g, 7.86 mmol, 1.00 equiv) was added and the mixture was then stirred 2 h. Water was then added (30 mL) followed by extraction of the aqueous layer with DCM (2 x 30 mL). The combined organic layers were dried over $MgSO_4$, filtered and the solvent was evaporated under reduced pressure. The resulting solid was triturated in hexane (10 mL). Filtration and removal of solvent *in vacuo* afforded phenyl(tri*iso*propylsilyl)iodonium triflate (**14**) (2.90 g, 11.2 mmol, 70% yield) as a colorless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (m, 2 H, Ar*H*), 7.65 (m, 1 H, Ar*H*), 7.52 (m, 2 H, Ar*H*), 1.15-1.01 (m, 21 H, TIPS); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.7, 132.5, 132.4, 119.7, 120.3

[1] C J. Helal, P. A. Magriotis, E. J. Corey, *J. Am. Chem. Soc.* **1996**, *118*, 10938.
[2] T. Kitamura, M. Kotani, Y. Fujiwara, *Synthesis* **1998**, *10*, 1416.

(q, *J*(C,F) = 319 Hz), 117.6, 117.6, 44.9, 18.3, 11.1; IR ν 3288 (w), 3088 (m), 2949 (m), 2894 (m), 2869 (w), 1563 (m), 1467 (w), 1451 (w), 1388 (w), 1281 (s), 1236 (s), 1221 (s), 1174 (s), 1068 (w), 1028 (s), 988 (m), 916 (m), 884 (m), 736 (s), 679 (m), 639 (s); Melting point: 109 – 114°C. HRMS (ESI) calcd for $C_{17}H_{26}ISi^+$ (M-OTf) 385.0843; found 385.0812; the reported values corresponded to the ones in literature.[3]

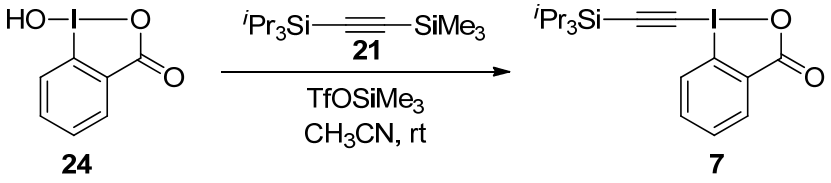
1-Hydroxy-1,2-benziodoxol-3-(1*H*)-one (24)



Following the reported procedure,[4] $NaIO_4$ (7.24 g, 33.8 mmol, 1.05 equiv) and 2-iodobenzoic acid (**23**) (8.00 g, 32.2 mmol, 1.00 equiv) were suspended in 30% (v:v) aq. AcOH (48 mL). The mixture was vigorously stirred and refluxed for 4 h. The reaction mixture was then diluted with cold water (180 mL) and allowed to cool to rt, protecting it from light. After 1 h, the crude product was collected by filtration, washed on the filter with ice water (3 x 20 mL) and acetone (3 x 20 mL), and air-dried in the dark to give the pure product **24** (8.3 g, 31 mmol, 98%) as a colorless solid.

^{1}H NMR (400 MHz, $(CD_3)_2SO$) δ 8.02 (dd, 1 H, *J* = 7.7, 1.4 Hz, Ar*H*), 7.97 (m, 1 H, Ar*H*), 7.85 (dd, 1 H, *J* = 8.2, 0.7 Hz, Ar*H*), 7.71 (td, 1 H, *J* = 7.6, 1.2 Hz, Ar*H*); ^{13}C NMR (100 MHz, $(CD_3)_2SO$) δ 167.7, 134.5, 131.5, 131.1, 130.4, 126.3, 120.4; IR ν 3083 (w), 3060 (w), 2867 (w), 2402 (w), 1601 (m), 1585 (m), 1564 (m), 1440 (m), 1338 (s), 1302 (m), 1148 (m), 1018 (w), 834 (m), 798 (w), 740 (s), 694 (s), 674 (m), 649 (m); the reported values correspond to the ones in literature.[3]

1-[(Tri*iso*-propylsilyl)ethynyl]-1,2-benziodoxol-3(1*H*)-one (TIPS-EBX, 7)



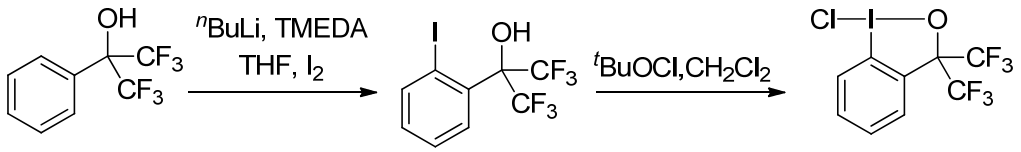
Following a reported procedure,[3] 2-iodosylbenzoic acid (**24**) (21.7 g, 82.0 mmol, 1.0 equiv) was charged in oven-dried three-neck 1L flask equipped with a magnetic stirrer. After 3 vacuum/nitrogen cycles, anhydrous acetonitrile (500 mL) was added via canula and cooled to 0 °C. Trimethylsilyltriflate (16.4 mL, 90.0 mmol, 1.1 equiv) was added dropwise via a dropping funnel over 30 min (no temperature increase was observed). After 15 min, (trimethylsilyl)(tri*iso*propylsilyl)acetylene (**21**) (23.0 g, 90.0 mmol, 1.1 equiv) was added via canula over 15 min (no temperature increase was observed). After 30 min, the suspension became an orange solution. After 10 min, pyridine (7.0 mL, 90 mmol, 1.1 equiv) was added via syringe. After 15 min, the reaction mixture was transferred in a one-neck 1L flask and

[3] J. P. Brand, J. Waser, *Angew. Chem., Int. Ed.* **2010**, *49*, 7304.
[4] L. Kraszkiewicz, L. Skulski, *Arkivoc*. **2003**, *6*, 120.

reduced under vacuum until a solid was obtained. The solid was dissolved in DCM (200 mL) and transferred in a 1L separatory funnel. The organic layer was added and washed with 1 M HCl (200 mL) and the aqueous layer was extracted with CH_2Cl_2 (200 mL). The organic layers were combined, washed with a saturated solution of $NaHCO_3$ (2 x 200 mL), dried over $MgSO_4$, filtered and the solvent was evaporated under reduced pressure. Recrystallization from acetonitrile (*ca* 120 mL) afforded **7** (30.1 g, 70.2 mmol, 86%) as colorless cristals.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44 (m, 1 H, Ar*H*), 8.29 (m, 1 H, Ar*H*), 7.77 (m, 2 H, Ar*H*), 1.16 (m, 21 H, TIPS). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 134.6, 132.3, 131.4, 131.4, 126.1, 115.6, 114.1, 64.6, 18.4, 11.1. IR ν 2943 (m), 2865 (m), 1716 (m), 1618 (m), 1604 (s), 1584 (m), 1557 (m), 1465 (m), 1439 (w), 1349 (m), 1291 (m), 1270 (w), 1244 (m), 1140 (m), 1016 (m), 999 (m), 883 (m), 833 (m), 742 (m), 702 (s), 636 (m); Melting point (Dec.) 170-176°C; Characterization data of **6** corresponded to the literature values.[3]

1-Chloro-1,3-dihydro-3,3-bis(trifluoromethyl)-1,2-benziodoxole (27)



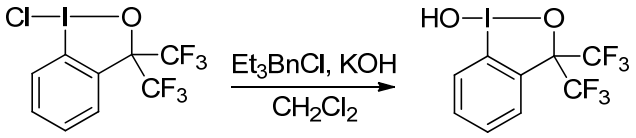
25 **26** **27**

Following a reported procedure,[5] TMEDA (distilled over KOH) (1.26 mL, 8.20 mmol, 0.2 equiv) was added to a solution of ^{n}BuLi (2.5 M in hexanes, 36.6 mL, 91.6 mmol, 2.2 equiv). After 15 min, the cloudy solution was cooled to 0 °C and **25** (7.0 mL, 42 mmol, 1 equiv) in THF (6 mL) was added dropwise. The reaction was stirred 30 min at 0 °C and then at RT overnight. I_2 (11.2 g, 44.0 mmol, 1.06 equiv) was then added portions wise at 0 °C and the mixture stirred at 0 °C for 30 min and 4 h at RT. The reaction was quenched with saturated NH_4Cl. Et_2O (100 mL) was added and the layers were separated. The aqueous layer was then extracted twice with Et_2O (3 x 50 mL). The organic layers were combined, washed twice with saturated NaS_2O_3 (2 x 50 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure to afford 15.6 g of crude **26** as an brown oil which was used without further purification.

The crude oil was dissolved in wet CH_2Cl_2 (40 mL) in the dark under air. ^{t}BuOCl (5.2 mL, 44 mmol, 1.05 equiv) was then added dropwise at 0 °C. After 30 min, the resulting suspension was filtered to afford **27** (7.30 g, 18.1 mmol, 43%) as a yellow solid. The mother liquors were carefully reduced to one third and filtered to afford more **27** (3.51 g, 8.71 mmol, 21%) as a yellow solid. Combined yield: 64%. Mp 167 – 169 °C, Lit: 166-168 °C.[5] ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, 1 H, *J* = 8.4 Hz, ArH), 7.85 (m, 1 H, ArH), 7.73 (m, 2 H, ArH). ^{13}C NMR (101 MHz, $CDCl_3$) δ 133.8, 132.1, 131.6, 129.7, 128.5, 122.8 (q, 289 Hz), 113.4, 84.8. The melting point and the ^{1}H NMR correspond to the reported values.[5]

1-Hydroxy-3,3-bis(trifluoromethyl)-3-(*1H*)-1,2-benziodoxole (28)

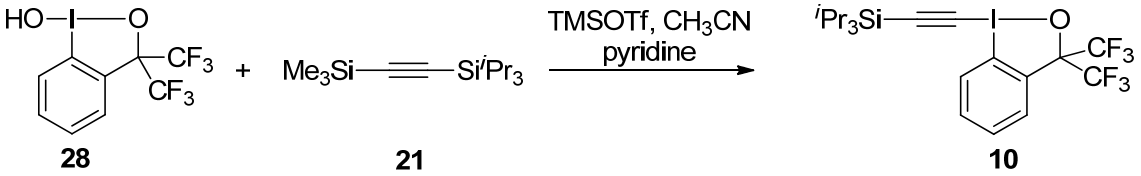
[5]. E. F. Perozzi, R. S. Michalak, G. D. Figuly, W. H. Stevenson, D. B. Dess, M. R. Ross, J. C. Martin, *J. Org. Chem.* **1981**, *46*, 1049.



27 **28**

Following a preported procedure,[6] Et_3BnNCl (83 mg, 0.36 mmol, 0.05 equiv) was added to a stirring solution of **27** (10.7 g, 26.5 mmol, 1 equiv) in CH_2Cl_2 (150 mL) and KOH (1.48 g, 26.5 mmol, 1 equiv) in water (28 mL). The reaction was stirred overnight under air. The organic layer was separated and dried over $MgSO_4$. The resulting solid was purified over a silica plug eluting with EtOAc,then recristallized in EtOAC (about 50 mL) and washed with pentane to afford **28** (7.42 g, 19.2 mmol, 73%) as a white solid. ^{1}H NMR (400 MHz, DMSO) δ 7.96 (m, 2 H, ArH), 7.73 (m, 2 H, ArH). ^{13}C NMR (101 MHz, DMSO) δ 133.3, 131.0, 130.8, 128.9, 127.9, 123.4 (q, J = 290 Hz), 117.2, 83.7 (m). IR 1464 (w), 1435 (w), 1290 (w), 1263 (m), 1185 (s), 1139 (s), 1103 (m), 1041 (w), 1021 (w), 952 (s), 760 (m), 730 (m), 692 (m).

1-[(Tri*iso*propylsilyl)ethynyl]-3,3-bis(trifluoromethyl)-3(*1H*)-1,2-benziodoxole (10)

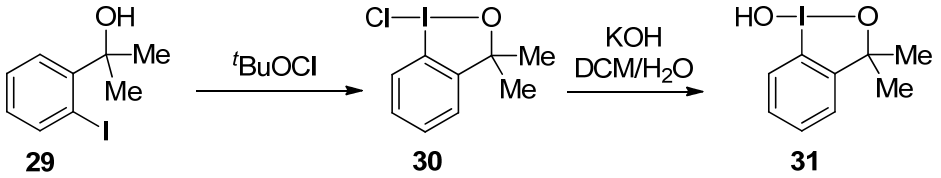


28 **21** **10**

TMSOTf (3.80 g, 17.1 mmol, 1.1 equiv) was added to **28** (6.00 g, 15.5 mmol, 1.0 equiv) in CH_2Cl_2 (200 mL) at RT. After 20 min, the solution was concentrated under reduced pressure at 0 °C and the reaction flask was refilled with Ar. Then the resulting yellow solid was dissolved in dry CH_3CN (200 mL). (Trimethylsilyl)(tri*iso*-propylsilyl)acetylene (**21**) (5.14 g, 20.2 mmol, 1.3 equiv) was added and after 20 min a few drops of pyridine were added. The reaction was then concentrated under vacuum, the residues were dissolved in Et_2O and the solutions filtered through a silica plug (eluant Et_2O). The resulting solid was recrystallized in pentane to afford **10** (5.43 g, 9.87 mmol, 64%) as a white crystalline solid. R_f (PET/Et_2O 95/5): 0.4. Mp 131 – 132 °C. ^{1}H NMR (400 MHz, $CDCl_3$) (*ca* 0.10 mmol/mL) δ 8.36 (dd, 1 H, J = 7.9, 1.7 Hz, ArH), 7.84 (d, 1 H, J = 6.7 Hz, ArH), 7.68 (m, 2H, ArH), 1.15 (m, 21 H, TIPS). ^{13}C NMR (101 MHz, $CDCl_3$) δ 132.7, 131.1, 129.9, 129.9 (m), 128.2, 123.6 (q, 288 Hz), 112.1, 110.8, 81.4 (m), 69.7, 18.5, 11.2. IR 2947 (m), 2868 (m), 2249 (w), 1566 (w), 1465 (m), 1438 (w), 1387 (w), 1264 (s), 1218 (m), 1184 (s), 1149 (s), 1071 (w), 994 (w), 951 (s), 910 (m), 873 (w), 732 (s), 696 (s), 655 (s), 655 (s). HRMS(ESI) calcd for $C_{20}H_{26}OF_6ISi^+$ (M+H) 551.0702, found 551.0723.

1-Hydroxy-3,3-dimethyl-3-(*1H*)-1,2-benziodoxole (31)

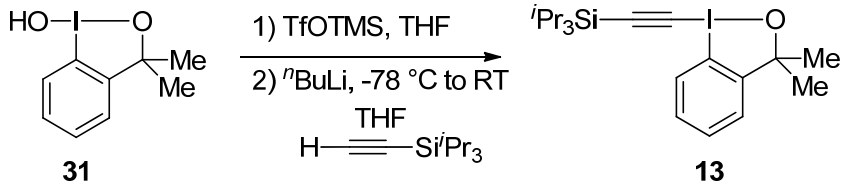
[6]. A. J. Blake, A. Novak, M. Davies, R. I. Robinson, S. Woodward, *Synth. Commun.* **2009,** *39*, 1065



Following a reported procedure,[7] ^{t}BuOCl (3.20 g, 29.5 mmol, 1.10 equiv) was added to **29** (7.03 g, 26.8 mmol, 1.00 equiv) at RT under air in the dark. The reaction was stirred for 30 min at RT. The solvent was removed under vacuum and the resulting solid dried in high vacuum to afford **30** (7.06 g, 23.8 mmol, 89%) as a yellow solid, which was used without further purification.

The solid **30** (7.06 g, 23.8 mmol, 1.00 equiv) was then dissolved in CH_2Cl_2 (60 mL) and KOH (1.34 g, 23.8 mmol, 1.00 equiv) in water (10 mL) was added. After 3 h, the organic layer was separated, dried over $MgSO_4$, filtered over $MgSO_4$ and concentrated. The resulting solid was recristallized in EtOAc (about 30 mL), washed with hexanes and dried under vacuum to afford **31** (3.64 g, 13.1 mmol, 55%) as a white solid. Mp 241 – 243 °C. ^{1}H NMR (400 MHz, DMSO) δ 7.79 (d, 1 H, *J* = 7.9 Hz, ArH), 7.52 (m, 2 H, ArH), 7.36 (d, 1 H, *J* = 7.4 Hz, ArH), 1.36 (s, 6 H, Me). ^{13}C NMR (101 MHz, $CDCl_3$) δ 150.0, 129.7, 129.2, 127.0, 126.2, 115.3, 79.4, 30.2. IR 1569 (w), 1464 (w), 1443 (w), 1263 (s), 1185 (s), 1140 (s), 1110 (s), 1020 (w), 952 (s), 761 (m), 730 (m), 690 (m), 643 (s).

1-[(Tri*iso*propylsilyl)ethynyl]-3,3-dimethyl-3(*1H*)-1,2-benziodoxole (13)

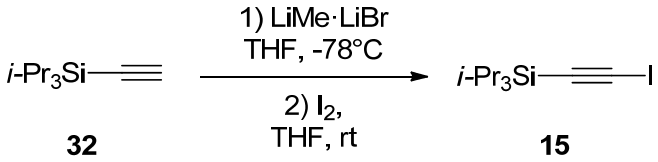


Freshly distilled trimethylsilyltriflate (250 µL, 1.38 mmol, 1 equiv) was added to a stirring solution of **31** (385 mg, 1.38 mmol, 1 equiv) in THF (40 mL) at RT. The solution was stirred at RT for 20 min and then cooled to -78 °C. In the meantime, ^{n}BuLi (2.5 M in hexanes, 554 µL, 1.38 mmol, 1 equiv) was added to a stirring solution of tri*iso*propylacetylene (310 µL, 1.38 mmol, 1 equiv) in THF (10 mL) at -78 °C. The solution was stirred for 30 min at -78 °C and then added via cannula to the first solution. The reaction was stirred for 1 h at -78 °C, warmed to RT and stirred 4 h. The reaction was quenched with saturated NH_4Cl (20 mL). The layers were separated and the aqueous layers were extracted with CH_2Cl_2 (20 mL). The organic layers were combined, washed with brine, dried over $MgSO_4$, filtered and concentrated under vacuum. The resulting oil was then purified by column chromatography (PET/Et_2O 6/4) to afford **13** (270 mg, 0.610 mmol, 43%) as a yellow oil. R_f(PET/Et_2O 6/4): 0.15. Mp 59 – 61°C. ^{1}H NMR (400 MHz, $CDCl_3$) (*ca* 0.16 mmol/mL) δ 8.23 (dd, 1 H, *J* = 8.2, 0.9 Hz, ArH), 7.52 (td, 1 H, *J* = 7.3, 1.0 Hz, ArH), 7.41 (ddd, 1 H, *J* = 8.6, 7.2, 1.5 Hz, ArH), 7.35 (dd, 1 H, *J* = 7.5, 1.5 Hz, ArH), 1.44 (s, 6 H, Me), 1.12 (s, 21 H, TIPS). ^{13}C NMR (101 MHz, $CDCl_3$) δ

[7]. R. A. Moss, B. Wilk, K. Kroghjespersen, J. T. Blair, J. D. Westbrook, *J. Am. Chem. Soc.* **1989,** *111*, 250

148.0, 130.4, 129.2, 127.4, 126.5, 111.0, 105.8, 80.8, 75.7, 31.5, 18.6, 11.4. IR 2945 (m), 2864 (m), 2064 (w), 1690 (w), 1562 (w), 1462 (m), 1436 (m), 1355 (w), 1244 (w), 1162 (w), 1116 (w), 1073 (w), 999 (m), 968 (m), 883 (m), 756 (m), 691 (s). HRMS(ESI) calcd for $C_{20}H_{32}OISi^+$ (M+H) 443.1267, found 443.1276.

2-Iodo-1-tri*iso*propylsilyl acetylene (15)



32 **15**

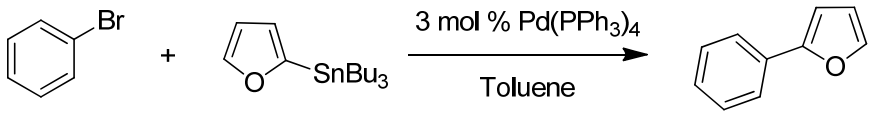
Following a reported procedure,[8] MeLi•LiBr (1.5 M in diethyl ether, 1.1.mL, 1.6 mmol, 1.0 equiv) was added to a stirred solution of tri*iso*propylsilylacetylene (**32**) (0.36 mL, 1.6 mmol, 1.0 equiv) in dry THF (1.8 mL), cooled at -78 °C, and the mixture was allowed to react for 1 h at that temperature. A solution of I_2 (457 mg, 1.80 mmol, 1.25 equiv) in dry THF (2.7 mL) was then added dropwise and the mixture was stirred for 1.5 h at -78°C. The mixture was then diluted with brine (6 mL) and the aqueous layer was extracted with ether (3 x 10 mL). The combined organic layers were washed with a saturated aqueous solution of $Na_2S_2O_3$ (3 x 20 mL), dried over $MgSO_4$ and concentrated under reduced pressure. Purification by column chromatography (SiO_2, hexane) afforded 2-iodo-1-tri*iso*propylsilyl acetylene (**15**) (470 mg, 1.52 mmol, 94% yield) as a colorless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ 1.10-1.04 (m, 21 H, TIPS); ^{13}C NMR (100 MHz, $CDCl_3$) δ 100.8, 18.5, 11.4 (one acetylene carbon was not resolved); the reported values correspond to the ones in literature.[8]

3. Synthesis of starting materials.

Furans **6a, 6b, 6c, 6d, 6e, 6f, 6j, 6k, 6l** are commercially available. The other starting materials were synthesized as shown below.

2-Phenylfuran (6g)



31 **33** **6g**

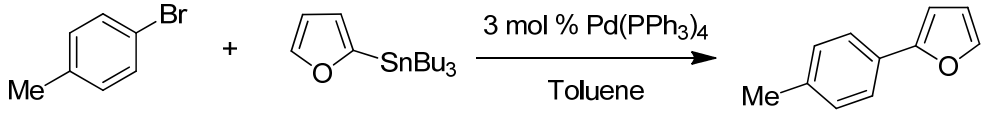
A 50 mL flask was charged with **33** (5.11 g, 14.3 mmol, 1.00 equiv), **31** (2.39 g, 15.2 mmol, 1.03 equiv), $Pd(PPh_3)_4$ (50 mg, 0.040 mmol, 0.003 equiv) and toluene (32 mL). The mixture was refluxed under N_2 overnight. Then, the reaction was filtered through a plug of celite and concentrated. The resulting oil was diluted with Et_2O (20 mL) and mixed with a saturated KF aqueous solution (10 mL). The mixture was stirred vigorously overnight, and filtered. The

[8] S. López, F. Fernández-Trillo, P. Midón, L. Castedo, C. Saá *J. Org. Chem.*, **2005**, *70*, 6346.

filtrate was concentrated and the resulting crude product was purified by column chromatography (wt% SiO_2/CsF, 90/10; Pentane) to afford **6g** (616 mg, 4.28 mmol, 45%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (dt, 2 H, *J* = 8.5, 1.5 Hz; *ArH*), 7.48 (dd, 1H, *J* = 1.8, 0.6 Hz; *FuranH*), 7.40 (m, 2 H; *ArH*), 7.27 (m, 1 H; *ArH*), 6.67 (dd, 1H, *J* = 3.2, 0.6 Hz; *FuranH*), 6.49 (dd, 1 H, *J* = 3.2, 1.8 Hz; *FuranH*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.0, 142.0, 130.9, 128.6, 127.3, 123.8, 111.6, 104.9. The ^{1}H NMR data corresponds to the literature. [9]

2-(p-Tolyl)furan (6h)

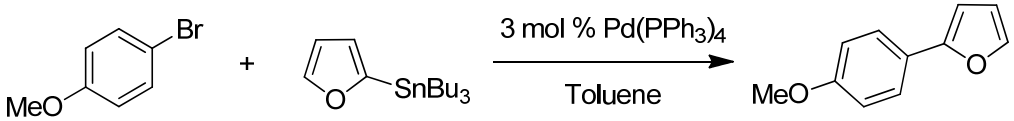


34 **33** **6h**

A 25 mL flask was charged with **34** (1.11 g, 6.60 mmol, 1.1 equiv), **33** (2.15 g, 6.00 mmol, 1.0 equiv), $Pd(PPh_3)_4$ (22 mg, 0.020 mmol, 0.003 equiv) and toluene (15 mL). The mixture was refluxed under N_2 overnight. Then, the reaction was filtered through a plug of celite and concentrated under reduced pressure. The resulting oil was diluted with Et_2O (20 mL) and mixed with a saturated KF aqueous solution (10 mL). The mixture was stirred vigorously overnight, and filtered. The filtrate was concentrated under reduced pressure and the resulting crude product was purified by column chromatography (wt% SiO_2/CsF, 90/10; Pentane) to afford **6h** (100 mg, 0.630 mmol, 11%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, 2 H, *J* = 8.1 Hz; *ArH*), 7.45 (d, 1 H, *J* = 0.7 Hz; *FuranH*), 7.19 (d, 2 H, *J* = 8.1 Hz; *ArH*), 6.59 (d, 1 H, *J* = 3.2 Hz; *FuranH*), 6.46 (dd, 1 H, *J* = 3.2, 1.7 Hz; *FuranH*), 2.37 (s, 3 H; *CH*$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.2, 141.6, 137.1, 129.3, 128.2, 123.8, 111.5, 104.2, 21.2. NMR data corresponds to the literature.[10]

2-(4-Methoxyphenyl)furan (6i)



35 **33** **6i**

A 25 mL flask was charged with **35** (2.16 g, 6.00 mmol, 1.0 equiv), **33** (1.24 g, 6.60 mmol, 1.1 equiv), $Pd(PPh_3)_4$ (22 mg, 0.020 mmol, 0.003 equiv), and degassed toluene (15 mL). The mixture was refluxed under N_2 overnight. Then, the reaction was filtered through a plug of celite and concentrated under reduced pressure. The resulting oil was diluted with Et_2O (20 mL) and mixed with a saturated KF aqueous solution (10 mL). The mixture was stirred vigorously overnight, and filtered. The filtrate was concentrated under reduced pressure and the resulting crude product was purified by column chromatography (wt% SiO_2/CsF, 90/10; Pentane) to afford **6i** (310 mg, 1.78 mmol, 30%)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, 2 H, *J* = 8.8 Hz; *ArH*), 7.43 (d, 1 H, *J* = 1.5 Hz; *FuranH*), 6.93 (d, 2 H, *J* = 8.8 Hz; *ArH*), 6.52 (d, 1 H, *J* = 3.3 Hz; *FuranH*), 6.45 (dd, 1 H, *J* =

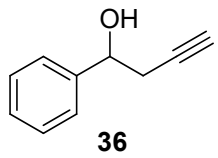
[8] S. Tanis, M. Deaton, L. Dixon, M. Mcmills, J. Raggon, M. Collins, *J. Org. Chem*. **1998**, *63*, 6914.
[9] C. Zhou, P. Chan, C. Che, *Org. Lett*. **2006**, *8*, 325.

3.3, 1.5 Hz; *FuranH*), 3.84 (s, 3 H; *CH_3*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 154.0, 141.4, 125.2, 124.0, 114.1, 111.5, 103.3, 55.3. The NMR data corresponds to the literature except the peak at 111.5 ppm in the ^{13}C spectra.[9]

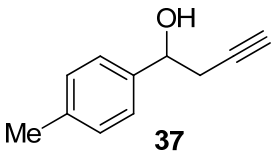
General procedure for the preparation of propargylic alcohols:

A 50 mL two-necked flask was charged with Mg (321 mg, 13.2 mmol, 1.32 equiv), $HgCl_2$ (2.7 mg, 0.10 mmol, 0.01 equiv) and dry diethyl ether (30 mL), then propargyl bromide was added dropwise (2.86 g, 12.0 mmol, 1.20 equiv). When the solution became homogeneous, the aldehyde (10.0 mmol, 1.00 equiv) was added dropwise. The reaction was quenched with a sat NH_4Cl solution (30 mL) when TLC (Pentane/EtOAc: 5/1) indicated that the benzaldehyde was completely consumed. The aqueous and organic layers were separated, the aqueous layer was extracted with diethyl ether (3×20 mL). The combined organic layers were dried over $MgSO_4$, concentrated under vaccum and purified by column chromatography (Pentane/EtOAc: 5/1).

Phenylbut-3-yn-1-ol (36) was obtained as a transparent oil (1.09 g, 7.46 mmol, 75%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42-7.30 (m, 5 H, *ArH*), 4.82 (m, 1 H, *CH*Ph), 3.23 (d, 1 H, *J* = 3.8 Hz, *OH*), 2.62 (m, 2 H, CH_2), 2.09 (t, 1 H, *J* = 2.6 Hz, alkyne *CH*) . ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.3, 128.1, 127.6, 125.6, 80.6, 72.0, 70.7, 28.9. The ^{1}H NMR data corresponds to the literature[11]

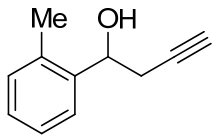


36



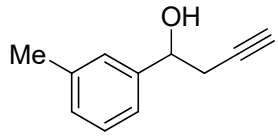
37

1-(p-Tolyl)but-3-yn-1-ol (37) was obtained as a yellow oil (1.56 g, 9.74 mmol, 97%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, 2 H, *J* = 8.1 Hz, *ArH*), 7.20 (d, 2 H, *J* = 8.1 Hz, *ArH*), 4.80 (m, 1 H, *CH*Ph) 3.25 (d, 1 H, *J* = 2.8 Hz, *OH*), 2.62 (m, 2 H, CH_2), 2.40 (s, 3 H, CH_3), 2.09 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.5, 137.1, 128.7, 125.5, 80.7, 71.8, 70.5, 28.8, 20.8. The NMR data corresponds to the literature[12]



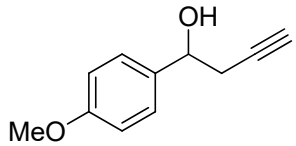
38

1-(m-Tolyl)but-3-yn-1-ol (38) was obtained as a yellow oil (1.55 g, 9.67 mmol, 97%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, 1 H, *J* = 7.1 Hz, *ArH*), 7.25 (m, 2 H, *ArH*), 7.18 (d, 1 H, *J* = 7.1 Hz, *ArH*), 5.12 (m, 1 H, *CH*Ph), 2.68 (d, 1 H, *J* = 3.4 Hz, *OH*), 2.63 (m, 2 H, CH_2), 2.39 (s, 3 H, CH_3), 2.11 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 140.4, 134.4, 130.3, 127.6, 126.2, 125.0, 80.9, 70.6, 68.6, 28.0, 18.9. The NMR data corresponds to the literature.[11]



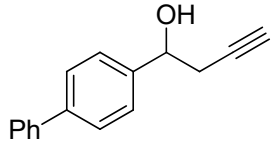
39

1-(o-Tolyl)but-3-yn-1-ol (**39)** was obtained as brown oil (1.53 g, 9.55 mmol, 96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (t, 1 H, *J* = 7.4 Hz *ArH*), 7.21 (m, 2 H, *ArH*), 7.15 (d, 1 H, *J* = 7.4 Hz, *ArH*), 4.82 (t, 1 H, *J* = 6.3 Hz, *CH*Ph), 2.83 (br s, 1 H, *OH*), 2.64 (dd, 2 H, *J* = 6.3, 2.5 Hz, CH_2), 2.40 (s, 3 H, CH_3), 2.09 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 142.3, 137.9, 128.5, 128.2, 126.3, 122.7, 80.8, 72.2, 70.7, 29.1, 21.3. The NMR data corresponds to the literature[11]



40

1-(4-Methoxyphenyl)but-3-yn-1-ol (40) was obtained as yellow oil (1.34 g, 7.60 mmol, 76%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, 2 H, *J* = 8.7 Hz, *ArH*), 6.93 (d, 2 H, *J* = 8.7 Hz, *ArH*), 4.81 (t, 1 H, *J* = 6.4 Hz, *CH*Ph), 3.81 (s, 3 H, OCH_3), 3.61 (br s, 1 H, *OH*), 2.64 (m, 2 H, CH_2), 2.14 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 134.6, 126.7, 113.2, 80.7, 71.4, 70.4, 54.7, 28.6. The NMR data corresponds to the literature[11]

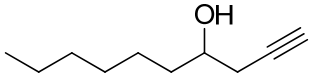


41

1-([1,1'-Biphenyl]-4-yl)but-3-yn-1-ol (41) was obtained as yellow solid (2.02, 9.17 mmol, 92%). Rf (Pentane / EtOAc = 6 / 1): 0.5. Mp 77 – 78°C ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67-7.61 (m, 4 H, *ArH*), 7.53-7.47 (m, 4 H, *ArH*), 7.38 (m, 1 H, *ArH*), 4.93 (t, 1 H, *J* = 6.3 Hz, *CH*Ph), 2.70 (dd, 2 H, *J* = 6.3, 2.6 Hz, CH_2), 2.66 (br s, 1 H, *OH*), 2.12 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.4, 140.8, 140.6,

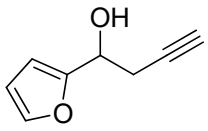
[10]. J. Chen, B. Captain, N. Takenaka, *Org. Lett*. **2011**, *13*, 1654.
[11]. B. M. Trost, M. Ngai, G. Dong, *Org. Lett*. **2011**, *13*, 1900.

128.7, 127.3, 127.1, 127.0, 126.2, 80.6, 72.0, 71.0, 29.3. IR 3460 (w), 3435 (w), 3396 (w), 3379 (w), 3369 (w), 3362 (w), 3352 (w), 3296 (m), 2910 (w), 2362 (w), 2341 (w), 2120 (w), 1487 (m), 1410 (w), 1267 (w), 1206 (w), 1184 (w), 1056 (m), 1008 (m), 840 (s), 767 (s), 737 (s). HRMS (ESI) calcd for $C_{16}H_{15}O^+$ $[M+H]^+$ 223.1117; found 223.1121.



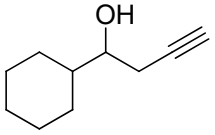
42

Dec-1-yn-4-ol (42) was obtained as yellow oil (1.21 g, 7.84 mmol, 78%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.64 (m, 1 H, *CH*OH), 2.65 (br s, 1 H, *OH*), 2.30 (ddd, 1 H *J* = 16.7, 5.1, 2.6 Hz, *CH*C≡CH), 2.22 (ddd, 1 H, *J* = 16.7, 6.5, 2.6 Hz, *CH*C≡CH), 1.96 (t, 1 H, *J* = 2.6 Hz, *C≡CH*), 1.51-1.12 (m, 10 H, C_5H_{10}), 0.79 (m, 3 H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 80.9, 70.0, 47.4, 35.9, 31.6, 29.0, 27.1, 25.3, 22.4, 13.8. The NMR data corresponds to the literature.[13]



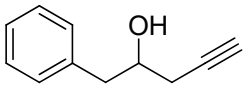
43

1-(Furan-2-yl)but-3-yn-1-ol (43) was obtained as yellow oil (700 mg, 5.14 mmol, 51%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (s, 1 H, *furanH*), 6.37 (m, 2 H, *furanH*), 4.88 (m, 1 H, *CH*OH), 3.35 (d, 1 H, *J* = 5.5 Hz, *OH*), 2.78 (m, 2 H, CH_2C≡CH), 2.10 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.6, 141.9, 110.0, 106.3, 79.9, 70.7, 65.7, 25.7. The NMR data corresponds to the literature.[12]



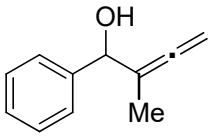
44

Cyclohexylbut-3-yn-1-ol (44) was obtained as transparent oil (1.42 g, 9.32 mmol, 93%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.50 (m, 1 H,*CH*OH), 2.82 (br s, 1 H, *OH*), 2.40 (m, 2 H, CH_2C≡CH), 2.08 (t, 1 H, *J* = 2.6 Hz, *CH*), 1.95-0.95 (m, 11 H, C_6H_{11}). ^{13}C NMR (101 MHz, $CDCl_3$) δ 81.2, 73.5, 70.2, 41.9, 28.7, 27.6, 26.0, 25.8, 25.6, 24.1. The NMR data corresponds to the literature.[14]



45

1-Phenylpent-4-yn-2-ol (45) was obtained as yellow oil (1.52 g, 9.53 mmol, 95%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (m, 2 H, *ArH*), 7.25 (m, 3 H, *ArH*), 3.99 (m, 1 H, *CH*OH), 2.88 (m, 2 H, CH_2Ph), 2.40 (m, 2 H, CH_2C≡CH), 2.22 (d, 1 H, *J* = 4.8 Hz, *OH*), 2.11 (t, 1 H, *J* = 2.6 Hz, *CH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 137.6, 129.3, 128.5, 126.5, 80.6, 71.0, 70.7, 42.3, 26.2. The NMR data corresponds to the literature. [15]



46

2-Methyl-1-phenyl-2,3-butadien-1-ol (46) was obtained as transparent oil (877 mg, 5,47 mmol, 55%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43-7.29 (m, 5 H, *ArH*), 5.13 (s, 1 H, *CH*OH), 4.91 (m, 2 H, CH_2), 2.96 (d, 1 H, *J* = 3.2 Hz, *OH*), 1.62 (t, 3 H, *J* = 3.0 Hz, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 204.8, 141.7, 128.0, 127.4, 126.3, 102.2, 77.1, 74.4, 14.1. The ^{1}H NMR data corresponds to the literature. [16]

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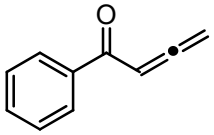
[12]. M, Hojo, R. Sakuragi, S. Okabe, A, Homosi, *Chem Commun.* **2001**, *4*, 357.
[13]. L. Guo, ; H. GaoP. Mayer, P. Knochel, *Chem.-Eur. J.* **2010**, *16*, 9829
[14]. L.R. Reddy, *Org. Lett*. **2012**, *14*, 1142.
[15]. A. McCluskey, W. I. Muntari, D.I. Young, *J. Org. Chem*. **2001**, *66*, 7811.

Typical procedure to prepare ketone allene:

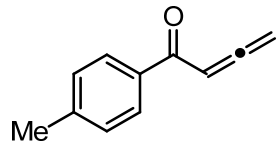
Typical procedure 1 (GPa): Following a reported procedure,[17] a solution of **36** (1.31 g, 9.00 mmol, 1 equiv) and CH_3CN (40 mL) was added into a solution of H_5IO_6 (2.15 g, 9.45 mmol, 1.05 equiv) and CH_3CN (40 mL) by an addition funnel at 0 ºC. Then, pyridiniumchlorochromat (PDC) (38 mg, 0.18 mmol, 0.02 equiv) was added into the mixture in three portions. The ice bath was removed and the reaction was diluted with EtOAc (100 mL) when TLC (Pentane/EtOAc: 10/1) showed that all starting material was consumed. The organic layer was washed with a mixture of brine and water (25 mL / 25 mL), sat $Na_2S_2O_3$ (50 mL), brine (50 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography (Pentane/EtOAc: 10/1).

Typical procedure 2 (GPb): A solution of **40** (352 mg, 2.00 mmol, 1.00 equiv) and dry CH_2Cl_2 (3.5 mL) was injected into a solution of Dess-martin reagent (1.02 g, 2.40 mmol, 1.20 equiv) and dry CH_2Cl_2 (14 mL) at room temperature under N_2. The reaction was diluted with Et_2O (30 mL) when TLC (Pentane/EtOAc: 10/1) showed that all starting material was consumed. The organic layer was washed with 1 M NaOH (40 mL). The aqueous layer was extracted with Et_2O (2 x 30 mL). Then the combined organic layers were washed with brine (30 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by column chromatography (Pentane/EtOAc: 10/1).



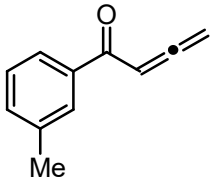
9a

1-Phenylbuta-2,3-dien-1-one (9a) was obtained following **GPa** as a brown solid (0.73 g, 5.5 mmol, 61%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (m, 2 H, *ArH*), 7.54 (m, 1 H, *ArH*), 7.44 (m, 2 H, *ArH*), 6.43 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.25 (d, 2 H, *J* = 6.5 Hz, *CH*$_2$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 217.0, 190.9, 137.4, 132.7, 128.6, 128.3, 93.2, 79.2. The NMR data corresponds to the literature.[18]



9b

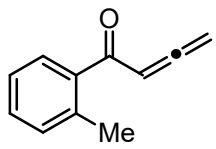
1-(*p*-Tolyl)buta-2,3-dien-1-one (9b) was obtained following **GPa** as a brown solid (1.1 g, 6.8 mmol, 76%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, 2 H, *J* = 8.2 Hz, *ArH*), 7.22 (d, 2 H, *J* = 8.2 Hz, *ArH*), 6.42 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.22 (d, 2 H, *J* = 6.5 Hz, *CH*$_2$), 2.38 (s, 3 H, *CH*$_3$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.7, 190.2, 143.5, 134.8, 129.0, 128.7, 92.9, 79.0, 21.5. The NMR data corresponds to the literature.[17]



9c

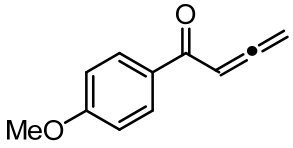
1-(*m*-Tolyl)buta-2,3-dien-1-one (9c) was obtained following **GPa** as a brown soild (0.83 g, 4.2 mmol, 57%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (m, 2 H, *ArH*), 7.28 (m, 2 H, *ArH*), 6.44 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.20 (d, 2 H, *J* = 6.5 Hz, *CH*$_2$), 2.35 (s, 3 H, *CH*$_3$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.3, 190.0, 137.6, 136.8, 133.0, 128.5, 127.7, 125.3, 92.5, 78.6, 20.7. The NMR data corresponds to the literature.[17]

[16]. M. Hunsen, *Tetrahedron Lett*. **2005**, *46*, 1651.
[17]. X. Fan, Y. Qu, Y. Wang, X. Zhang, J. Wang, *Tetrahedron Lett*. **2010**, *51*, 2123.



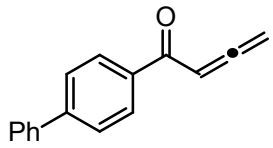
9d

1-(*o*-Tolyl)buta-2,3-dien-1-one (9d) was obtained following **GPa** as a brown soild (0.97 g, 6.0 mmol, 67%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 (d, 1 H, *J* = 7.7 Hz, *ArH*), 7.33 (m, 1 H, *ArH*), 7.20 (m, 2 H, *ArH*), 6.19 (t, 1 H, *J* = 6.4 Hz, *CH*), 5.10 (d, 2 H, *J* = 6.5 Hz, CH_2), 2.41 (s, 3 H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 217.7, 195.7, 138.1, 136.7, 131.1, 130.5, 128.2, 124.9, 96.6, 79.0, 19.9. Compound **8d** is known. [19]



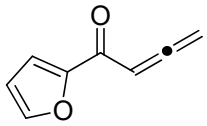
9e

1-(4-Methoxyphenyl)buta-2,3-dien-1-one (9e) was obtained following **GPb** as a yellow solid (232 mg, 1.33 mmol, 67%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (d, 2 H, *J* = 8.8 Hz, *ArH*), 6.86 (d, 2 H, *J* = 8.8 Hz, *ArH*), 6.39 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.18 (d, 2 H, *J* = 6.5 Hz, CH_2), 3.79 (s, 3 H, CH_3). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.2, 188.7, 163.2, 130.7, 130.1, 113.4, 92.5, 78.8, 55.2. The ^{1}H NMR data corresponds to the literature. [20]



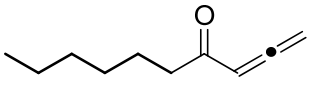
9f

1-([1,1'-Biphenyl]-4-yl)buta-2,3-dien-1-one (9f) was obtained following **GPa** as a brown solid (1.31 g, 5.94 mmol, 66%). R_f (Pentane/EtOAc 20/1): 0.4 Mp 93 – 94°C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, 2 H, *J* = 8.3 Hz, *ArH*), 7.67 (d, 2 H, *J* = 8.3 Hz, *ArH*), 7.62 (d, 2 H, *J* = 7.5 Hz, *ArH*), 7.47 (t, 2 H, *J* = 7.5 Hz, *ArH*), 7.40 (m, 1 H, *ArH*), 6.50 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.28 (d, 2 H, *J* = 6.5 Hz, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.7, 190.0, 145.2, 139.5, 135.8, 129.1, 128.7, 128.0, 127.0, 126.8, 92.9, 79.1. IR 3061 (w), 3033 (w), 2362 (w), 2340 (w), 2250 (w), 1960 (m), 1931 (w), 1648 (m), 1603 (m), 1559 (w), 1487 (w), 1450 (w), 1418 (w), 1349 (w), 1313 (w), 1279 (m), 1220 (m), 1193 (w), 1097 (w), 1007 (w), 982 (m), 910 (m), 850 (m), 732 (s). HRMS (ESI) calcd for $C_{16}H_{13}O^{+}$ $[M+H]^{+}$ 221.0961; found 221.0996.



9g

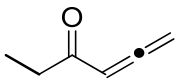
1-(Furan-2-yl)buta-2,3-dien-1-one (9g) was obtained following **GPb** as yellow oil (111 mg, 0.840 mmol, 42%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, 1 H, *J* = 1.6 Hz, *FuranH*), 7.28 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 6.54 (dd, 1 H, *J* = 3.5, 1.6 Hz, *FuranH*), 6.43 (t, 1 H, *J* = 6.5 Hz, *CH* allene), 5.33 (d, 2 H, *J* = 6.5 Hz, CH_2). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.0, 177.7, 152.3, 146.5, 118.0, 112.3, 92.4, 79.7. The NMR data corresponds to the literature.[21]



9h

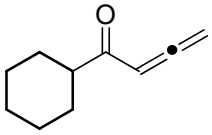
Deca-1,2-dien-4-one (9h) was obtained following **GPb** as yellow oil (147 mg, 0.964 mmol, 48%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.61 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.10 (d, 2 H, *J* = 6.5 Hz, CH_2 allene), 2.45 (t, 2 H, *J* = 7.4 Hz, *HexylH*), 1.45 (m, 2 H, *HexylH*), 1.15 (m, 6H, *HexylH*), 0.74 (t, 3 H *J* = 6.8 Hz, CH_3). The NMR data corresponds to the literature.[22]

[18]. B. Yoo, S. Lee, K. Choi, S. Keum, J. Ko, K. Choi, J. Kim, *Tetrahedron Lett.* **2001**, *42*, 7287.
[19]. L. O. Davis, S. L. Tobey, *Tetrahedron Lett*. **2010**, *51*, 6078.
[20]. S. A. Hashmi, T. L. Ruppert, T. Knoefel, J. W. Bats, *J. Org. Chem*. **1997**, *62*, 7295.
[21]. S. Ma, S. Yu, S. Yin, *J. Org. Chem*. **2003**, *68*, 8996.



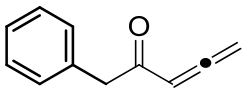
9i

Hexa-4,5-dien-3-one (9i) was obtained following **GPb** as yellow oil (50 mg, 0.52 mmol, 26%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.70 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.17 (d, 2 H, *J* = 6.5 H, *CH₂* allene), 2.57 (q, 2 H, *J* = 7.4 Hz, *CH₂*CH₃), 1.02 (t, 3 H, *J* = 7.4 Hz, CH₂*CH₃*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.3, 201.1, 96.1, 79.2, 32.4, 8.2. The NMR data corresponds to the literature.[23]



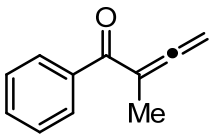
9j

1-Cyclohexylbuta-2,3-dien-1-one (9j) was obtained following **GPb** as yellow oil (200 mg, 1.33 mmol, 67%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.65 (t, 1 H, *J* = 6.5 Hz, *CH* allene), 5.15 (d, 2 H, *J* = 6.5 Hz, *CH₂* allene), 2.78 (t, 1 H, *J* = 11.2 Hz, *cyclohexylH*), 1.65 (m, 5 H, *cyclohexylH*), 1.15 (m, 5H, *cyclohexylH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 216.0, 203.5, 95.2, 79.0, 46.8, 28.9, 25.7, 25.4. The NMR data corresponds to the literature. [24]



9k

Phenylpenta-3,4-dien-2-one (9k) was obtained following **GPb** as a yellow solid. (193 mg, 1.22 mmol, 61%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (m, 2 H, *ArH*), 7.28 (m, 3 H, *ArH*), 5.86 (t, 1 H, *J* = 6.5 Hz, *CH*), 5.31 (d, 2 H, *J* = 6.5 Hz, *CH₂* allene), 3.94 (s, 2 H, *CH₂*Ph). The NMR data corresponds to the literature. [25]



16

2-Methyl-1-phenylbuta-2,3-dien-1-one (16) was obtained following **GPb** as yellow oil (108 mg, 0.682 mmol, 34%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 (m, 1 H, *ArH*), 7.50 (m, 1 H, *ArH*), 7.39 (m, 2 H, *ArH*), 5.02 (q, 2 H, *J* = 2.9 Hz, *CH₂*), 2.01 (t, 3 H, *J* = 2.9 Hz, *CH₃*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 217.6, 192.0. 138.1, 131.9, 129.0, 127.8, 102.0, 78.4, 14.7.[22]

4. C2-selective direct alkynylation

General procedures for α alkynylation reaction:

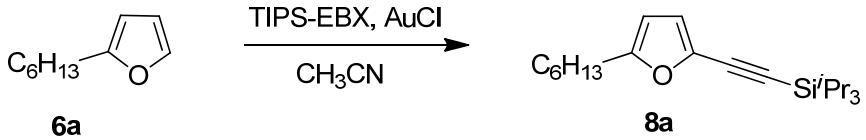
General procedure 1 (GP1): TIPS-EBX (206 mg, 0.480 mmol, 1.20 equiv), AuCl (4.6 mg, 0.020 mmol, 0.050 equiv) and furan derivatives (0.40 mmol, 1.0 equiv) were added into of CH_3CN (1.0 mL) under air. The mixture was stirred for 26 hours at room temperature. The organic layer was washed with HCl 1 M (20 mL), the aqueous layer was extracted with CH_2Cl_2 (20 mL). The combined organic layers were washed with saturated Na_2CO_3 aqueous solution (20 mL), brine (20 mL), dried over $MgSO_4$ and concentrated under reduced pressure.

General procedure 2 (GP2): TIPS-EBX (171 mg, 0.400 mmol, 1.00 equiv) and AuCl (4.6 mg, 0.020 mmol, 0.050 equiv) were added into of furan derivatives (1.0 mL) (solvent free) under air. The mixture was stirred for 26 hours at room temperature. The organic layer was washed with HCl 1 M (20 mL), the aqueous layer was extracted with CH_2Cl_2 (20 mL). The combined organic layers were washed with saturated Na_2CO_3 aqueous solution (20 mL), brine (20 mL), dried over $MgSO_4$ and concentrated under reduced pressure.

[22]. W. D. Huntsman, T. Yin, *J. Org. Chem*. **1983**, *48*, 3813.
[23]. A. Denichoux, F. Ferreira, F. Chemla, *Org. Lett*. **2004**, *6*, 3509. carbon on 192 ppm doesn't fit so well
[24]. S. Lucas, U. Kazmaier, *Synlett*, **2006**, *2*, 255.

General procedure 3 (GP3): TIPS-EBX (206 mg, 0.480 mmol, 1.20 equiv), AuCl (4.6 mg, 0.020 mmol, 0.050 equiv) and furan derivatives (0.40 mmol, 1.0 equiv) were added into CH_3CN (1.0 mL) under air. The mixture was stirred for 26 hours at 60 ºC. The organic layer was washed with HCl 1 M (20 mL), the aqueous layer was extracted with CH_2Cl_2 (20 mL). The combined organic layers were washed with saturated Na_2CO_3 aqueous solution (20 mL), brine (20 mL), dried over $MgSO_4$ and concentrated under reduced pressure.

((5-Hexylfuran-2-yl)ethynyl)triisopropylsilane (8a)



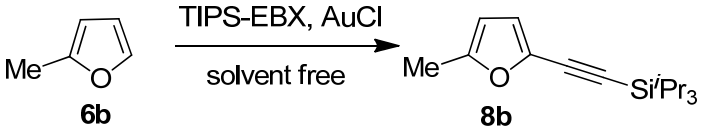
6a **8a**

Following the conditions described in **GP1**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8a** as yellow oil (119 mg, 0.360 mmol, 90%).

R_f (Pentane): 0.5;

^{1}H NMR (400MHz, $CDCl_3$) δ 6.50 (d, 1 H, *J* = 3.3 Hz, *FuranH*), 5.95 (d, 1 H, *J* = 3.2 Hz, *FuranH*), 2.60 (t, 2 H, *J* = 7.6 Hz, *HexylH*), 1.63 (t, 2 H, *J* = 6.9 Hz, *HexylH*), 1.32 (m, 6 H, *HexylH*), 1.12 (m, 21 H, *TIPS*), 0.89 (m, 3 H, *HexylH*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.9, 135.4, 116.7, 105.9, 96.7, 95.3, 31.5, 28.8, 28.3, 27.8, 22.5, 18.6, 14.0, 11.3; IR 2940 (s), 2865 (s), 2149 (m), 1528 (w), 1463 (m), 1225 (w), 1197 (w), 1071 (w), 1015 (m), 996 (m), 964 (w), 883 (s). HRMS (ESI) calcd for $C_{21}H_{37}OSi^+$ $[M+H]^+$ 333.2608; found 333.2604.

Triisopropyl((5-methylfuran-2-yl)ethynyl)silane (8b)



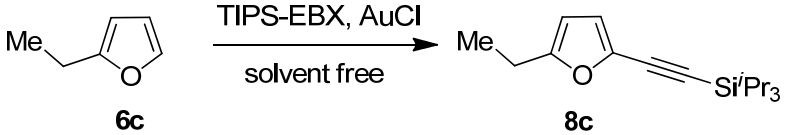
6b **8b**

Following the conditions described in **GP2**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8b** as yellow oil (82 mg, 0.31 mmol, 78%).

R_f (Pentane): 0.5.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.50 (d, 1 H, *J* = 2.9 Hz, *FuranH*), 5.95 (m, 1 H, *FuranH*), 2.30 (s, 3 H, *CH₃*), 1.12 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.4, 135.6, 116.8, 106.8, 96.6, 95.3, 18.6, 13.9, 11.2; IR 2943 (s), 2865 (s), 2150 (m), 1595 (w), 1530 (w), 1464 (m), 1384 (w), 1232 (m), 1219 (w), 1197 (w), 1138 (w), 1072 (w), 1020 (m), 996 (m), 947 (w), 920 (w), 883 (s). HRMS (ESI) calcd for $C_{16}H_{27}OSi^+$ $[M+H]^+$ 263.1826; found 263.1821.

((5-Ethylfuran-2-yl)ethynyl)triisopropylsilane (8c)



6c **8c**

Following the conditions described in **GP2**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8c** as colorless oil (87 mg, 0.32 mmol, 79%).

R_f (Pentane): 0.4.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.51 (d, 1 H, *J* = 3.2 Hz, *FuranH*), 5.96 (m, 1 H, *FuranH*), 2.64 (q, 2 H, *J* = 7.5 Hz, *CH₂*), 1.23 (t, 3 H, *J* = 7.5 Hz, *CH₃*), 1.13 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.0, 135.5, 116.7, 105.2, 96.7, 95.3, 21.6, 18.6, 12.0, 11.3; IR 2943

(m), 2866 (m), 2149 (m), 1590 (w), 1529 (w), 1464 (m), 1384 (w), 1226 (m), 1197 (w), 1071 (w), 1016 (m), 996 (m), 964 (m), 909 (s), 883 (s). HRMS (ESI) calcd for $C_{17}H_{29}OSi^+$ $[M+H]^+$ 277.1982; found 277.1980.

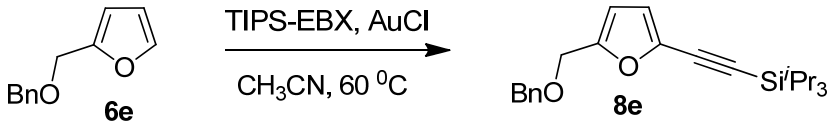
((5-(*tert*-Butyl)furan-2-yl)ethynyl)triisopropylsilane (8d)

Following the conditions described in **GP1**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8d** as yellow oil (68 mg, 0.22 mmol, 56%).

R_f (Pentane): 0.4;

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.49 (d, 1 H, *J* = 3.3 Hz, *FuranH*), 5.93 (d, 1 H, *J* = 3.3 Hz, *FuranH*), 1.28 (s, 9 H, *^{t}Bu*), 1.13 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 165.4, 135.3, 116.7, 103.2, 97.0, 95.1, 32.9, 29.0, 18.6, 11.3; IR 2963 (s), 2945 (s), 2867 (s), 2150 (m), 1584 (w), 1527 (w), 1463 (m), 1367 (w), 1276 (w), 1235 (w), 1215 (w), 1193 (w), 1076 (w), 1032 (w), 1019 (m), 998 (w), 969 (w), 920 (w), 884 (s). HRMS (ESI) calcd for $C_{19}H_{33}OSi^+$ $[M+H]^+$ 305.2295; found 305.2294.

((5-((Benzyloxy)methyl)furan-2-yl)ethynyl)triisopropylsilane (8e)

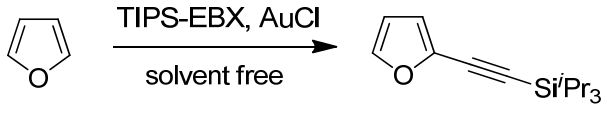


Following the conditions described in **GP3**, the crude product was purified by flash column chromatography (SiO_2; Pentane/CH_3COOEt 50/1) to afford **8e** as yellow oil (80 mg, 0.22 mmol, 55%). The analytic sample was repurified by HPLC (column: Chromolith prep, Eluent: pentane/EtOAct 50/1).

R_f (Pentane/EtOAc 50/1): 0.3

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.27 (m, 5 H, *ArH*), 6.55 (d, 1 H, *J* = 3.3 Hz, *FuranH*), 6.30 (d, 1 H, *J* = 3.3 Hz, *FuranH*), 4.56 (m, 2 H, *CH_2*), 4.46 (s, 2 H, *CH_2*), 1.12 (m, 21 H, *TIPS*); ^{13}C NMR (151 MHz, $CDCl_3$) δ 152.5, 137.7, 137.4, 128.4, 128.4, 127.9, 127.8, 127.6, 116.4, 110.3, 96.3, 96.1, 72.1, 63.8, 18.6, 11.2; IR 2948 (s), 2866 (s), 2033 (s), 1457 (s), 1456 (s), 1436 (m), 1250 (w), 1249 (w), 1093 (w), 1092 (w), 1088 (w), 1087 (w), 1081 (w), 1080 (w), 1071 (w), 1028 (w), 1017 (m), 945 (w), 912 (w), 884 (w), 851 (w), 803 (w). HRMS (ESI) calcd for $C_{23}H_{33}O_2Si^+$ $[M+H]^+$ 369.2244; found 369.2246.

(Furan-2-ylethynyl)triisopropylsilane (8f)

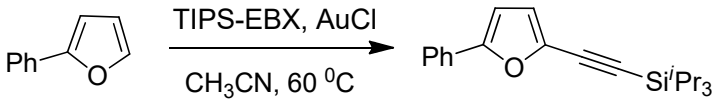


Following the conditions described in **GP2**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8f** as colorless oil (60 mg, 0.24 mmol, 61%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, 1 H, *J* = 0.8 Hz, *FuranH*), 6.59 (d, 1 H, *J* = 3.1 Hz, *FuranH*), 6.37 (dd, 1 H, *J* = 3.2, 0.8 Hz, *FuranH*), 1.13 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.2, 137.4, 115.5, 110.7, 96.1, 96.0, 18.6, 11.2; IR 3331 (w), 3330 (w), 3329 (w), 3328 (w), 2972 (w), 2944 (w), 2931 (w), 2866 (w), 2148 (w), 1490 (w), 1460 (w), 1383 (w), 1090 (m), 1049 (s), 997 (w), 970 (w), 882 (s), 820 (w). HRMS (ESI) calcd for $C_{15}H_{25}OSi^+$ $[M+H]^+$ 249.1669; found 249.1704.

Triisopropyl((5-phenylfuran-2-yl)ethynyl)silane (8g)



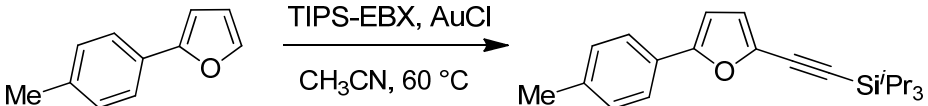
6g **8g**

Following the conditions described in **GP3**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8g** as yellow oil (88 mg, 0.27 mmol, 68%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (dd, 2 H, *J* = 8.5, 1.4 Hz, *ArH*), 7.38 (m, 2 H, *ArH*), 7.29 (m, 1 H, *ArH*), 6.67 (m, 1 H, *FuranH*), 6.61 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 1.16 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.4, 136.6, 130.2, 128.7, 127.9, 124.2, 117.9, 106.0, 96.9, 96.5, 18.6, 11.3; IR 2943 (s), 2865 (s), 2148 (m), 2112 (w), 1755 (w), 1721 (w), 1695 (w), 1607 (w), 1588 (w), 1522 (w), 1483 (m), 1463 (s), 1228 (m), 1202 (m), 1177 (w), 1159 (w), 1072 (w), 1023 (s), 997 (m), 970 (m), 922 (w), 914 (w), 883 (s). HRMS (ESI) calcd for $C_{21}H_{29}OSi^+$ $[M+H]^+$ 325.1982; found 325.1967.

Triisopropyl((5-(p-tolyl)furan-2-yl)ethynyl)silane (8h)



6h **8h**

Following the conditions described in **GP3**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8h** as yellow oil (89 mg, 0.26 mmol, 66%).

R_f (Pentane): 0.6

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, 2 H, *J* = 8.1 Hz, *ArH*), 7.19 (d, 2 H, *J* = 8.0 Hz, *ArH*), 6.67 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 6.56 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 2.37 (s, 3 H, *CH*$_3$), 1.14 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.6, 137.8, 136.2, 129.3, 127.5, 124.1, 117.9, 105.3, 96.7, 96.6, 21.3, 18.6, 11.3; IR 2943 (s), 2865 (s), 2148 (m), 1532 (w), 1490 (s), 1463 (m), 1384 (w), 1228 (w), 1201 (w), 1185 (w), 1184 (w), 1072 (w), 1021 (s), 997 (m), 970 (m), 922 (w), 883 (s), 820 (s). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2140.

Triisopropyl((5-(4-methoxyphenyl)furan-2-yl)ethynyl)silane (8i)

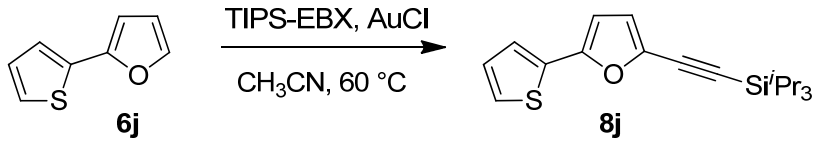
6i **8i**

Following the conditions described in **GP3**, the crude product was purified by flash column chromatography (SiO_2; Pentane/EtOAc 100/1) to afford **8i** as yellow oil (100 mg, 0.280 mmol, 71%).

R_f (Pentane/EtOAc 50/1): 0.1

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, 2 H, *J* = 8.8 Hz, *ArH*), 6.94 (d, 2 H, *J* = 8.8 Hz, *ArH*), 6.68 (d, 1 H, *J* = 3.4 Hz, *FuranH*), 6.50 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 3.86 (s, 3 H, *OCH₃*), 1.15 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.5, 154.5, 136.0, 125.7, 123.3, 118.0, 114.1, 104.5, 96.7, 96.7, 55.4, 18.7, 11.3; IR 2949 (w), 2948 (w), 2947 (w), 2866 (w), 2865 (w), 2365 (w), 2148 (w), 2147 (w), 1751 (m), 1750 (m), 1490 (w), 1460 (m), 1459 (m), 1366 (w), 1253 (m), 1166 (s), 956 (m), 879 (m), 836 (w). HRMS (ESI) calcd for $C_{22}H_{31}O_2Si^+$ $[M+H]^+$ 355.2088; found 355.2081.

Triisopropyl((5-(thiophen-2-yl)furan-2-yl)ethynyl)silane (8j)



6j **8j**

Following the conditions described in **GP3**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8j** as yellow oil (73 mg, 0.22 mmol, 56%).

R_f (Pentane): 0.7.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (dd, 1 H, *J* = 3.6, 1.1 Hz, *ThiopheneH*), 7.23 (dd, 1 H, *J* = 5.1, 1.1 Hz, *ThiopheneH*), 7.03 (dd, 1 H, *J* = 5.0, 3.7 Hz, *ThiopheneH*), 6.64 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 6.45 (d, 1 H, *J* = 3.5 Hz, *FuranH*), 1.14 (m, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 149.8, 136.2, 133.1, 127.7, 124.8, 123.6, 117.9, 106.0, 97.3, 96.2, 18.6, 11.3; IR 2948 (s), 2866 (s), 2147 (w), 2146 (w), 2145 (w), 1713 (m), 1646 (s), 1530 (w), 1464 (m), 1259 (w), 1243 (w), 1007 (m), 997 (m), 920 (w), 887 (w). HRMS (ESI) calcd for $C_{19}H_{27}OSSi^+$ $[M+H]^+$ 331.1546; found 331.1542.

((4,5-Dimethylfuran-2-yl)ethynyl)triisopropylsilane (8k)

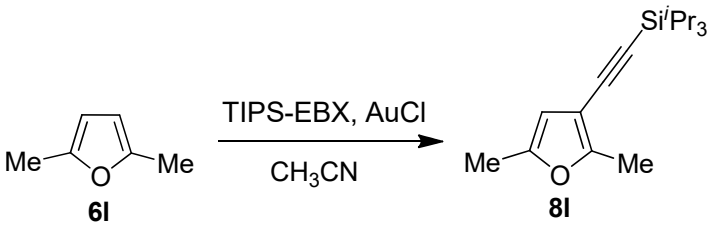
6k **8k**

Following the conditions described in **GP1**, the crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8k** as yellow oil (71 mg, 0.26 mmol, 65%).

R_f (Pentane): 0.6;

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.40 (s, 1 H, FuranH), 2.21 (s, 3 H, CH_3), 1.92 (s, 3 H, CH_3), 1.13 (m, 21 H, TIPS); ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.9, 134.3, 119.1, 115.3, 96.8, 95.2, 18.6, 11.6, 11.2, 9.7; IR 2943 (s), 2865 (s), 2150 (m), 1622 (w), 1533 (w), 1463 (m), 1245 (m), 1138 (w), 1016 (w), 996 (m), 950 (w), 919 (w), 883 (s), 817 (w). HRMS (ESI) calcd for $C_{17}H_{29}OSi^+$ $[M+H]^+$ 277.1982; found 277.1985.

((2,5-Dimethylfuran-3-yl)ethynyl)triisopropylsilane (8l)



Following the modified conditions described in **GP2**. TIPS-EBX (171 mg, 0.400 mmol, 1.00 equiv) and AuCl (4.6 mg, 0.020 mmol, 0.05 equiv) were added in **6l** (1.0 mL) (solvent free) under air. The mixture was stirred for 26 hours at 60 °C. The organic layer was washed with 1 M HCl (20 mL), the aqueous layer was extracted with CH_2Cl_2 (20 mL). The combined organic layers were washed with a saturated aqueous solution of Na_2CO_3 (20 mL) and brine (20 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The crude product was purified by flash column chromatography (SiO_2; Pentane) to afford **8l** as yellow oil (50 mg, 0.18 mmol, 45%).

R_f (Pentane): 0.5.

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.92 (s, 1 H, *FuranH*), 2.32 (s, 3 H, *CH$_3$*), 2.21 (s, 3 H, *CH$_3$*), 1.10 (s, 21 H, *TIPS*); ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.5, 149.6, 108.2, 104.1, 99.6, 92.3, 18.7, 13.2, 12.6, 11.3; IR 2943 (m), 2865 (s), 2154 (w), 1746 (w), 1716 (w), 1464 (m), 1450 (m), 1449 (m), 1386 (w), 1342 (w), 1281 (w), 1237 (w), 1191 (m), 1116 (w), 1096 (w), 1072 (w), 996 (m), 921 (w), 883 (s). HRMS (ESI) calcd for $C_{17}H_{29}OSi^+$ $[M+H]^+$ 277.1982; found 277.1989.

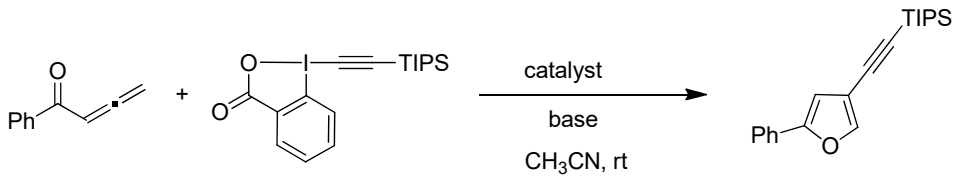
5. Domino cyclization-alkynylation reaction:

Optimization of the reaction:

TIPS-EBX **(7)** (51 mg, 0.12 mmol, 1.2 equiv), base (0.12 mmol, 1.2 equiv) and catalyst (0.005 mmol, 0.050 equiv) were added into a solution of 1-phenylbuta-2,3-dien-1-one (**9a**) (15 mg, 0.10 mmol, 1.0 equiv) and CH_3CN (5 mL). The reaction was stopped after 72 h. Isolated yields after column chromatography (SiO_2, pentane) are given.

The complete list of experiments for the optimization of the domino alkynylation with TIPS-EBX (**7**) reagent is shown in Table S1.

Table S1: Optimization with TIPS-EBX (**7**) reagent:



9a **7** **11a**

Entry	Catalyst	Base	Yield (%)
1	**12**	NEt_3	0
2	**12**	Py	0
3	**12**	DBU	<5
4	**12**	KO*t*Bu	0
5	**12**	Cs_2CO_3	<5
6	**12**	K_2CO_3	10
7	**12**	Na_2CO_3	31
8	**12**	Li_2CO_3	<5
9	**12**	$NaHCO_3$	22
10	AuCl	Na_2CO_3	0
11	Au(IPr)Cl + 5mol % AgOTs	Na_2CO_3	0
12	$AuCl_3$	Na_2CO_3	0[a]
13	$NaAuCl_4$	Na_2CO_3	<5
14	$Au(OAc)_3$	Na_2CO_3	0
15	$InCl_3$	Na_2CO_3	0
16	$PtCl_2$	Na_2CO_3	<5
17	$PdCl_2(CH_3CN)_2$	Na_2CO_3	<5

[a] Only cyclization product **6g** was obtained

General procedure: 1-[(tri*iso*propylsilyl)ethynyl]-3,3-bis(trifluoromethyl)-3(*1H*)-1,2-benziodoxole (**10**) (110 mg, 0.200 mmol, 2.00 equiv)**,** Na_2CO_3 (21 mg, 0.20 mmol, 2.0 equiv) and catalyst (0.005 mmol, 0.050 equiv) were added into a solution of 1-phenylbuta-2,3-dien-1-one (**9a**) (15 mg, 0.10 mmol, 1.0 equiv) and *iso*-propanol (5 mL). The reaction was stopped after 72 h. 1 mL of mixture was mixed with 0.16 mL n-decane solution (0.125 M in CH_3CN) and injected into the GC-MS chromatographer. The following oven program was used: Initial temperature: 50 °C, Ramp: 10.0 °C/min to 250 °C, hold 25 min at 250 °C). Yields were determined by GC-MS, based on the following calibration.

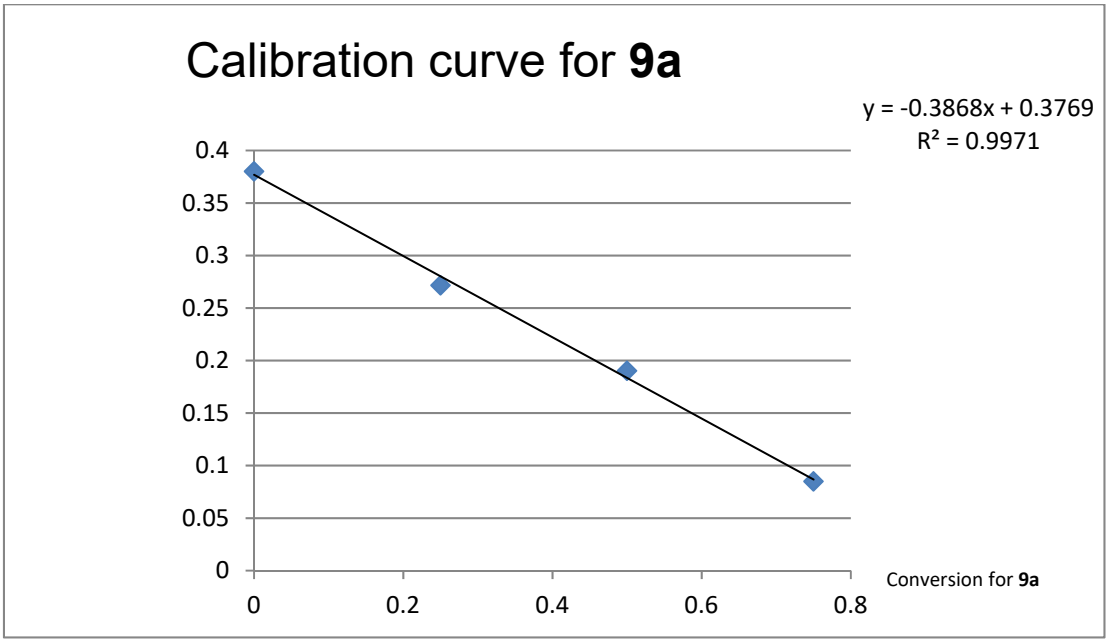
A 0.125 M standard solution was prepared by dissolving n-decane (0.242 mL, 1.25 mmol) in CH_3CN (10 mL).

1-Phenylbuta-2,3-dien-1-one (**9a**) (7.2 mg, 0.054 mmol) was dissolved in CH_2Cl_2 (1.0 mL) (solution O).

- 25 µL of solution O were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution A;
- 50 µL of solution O were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution B;
- 75 µL of solution O were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution C;

- 100 µL of solution O were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution D;

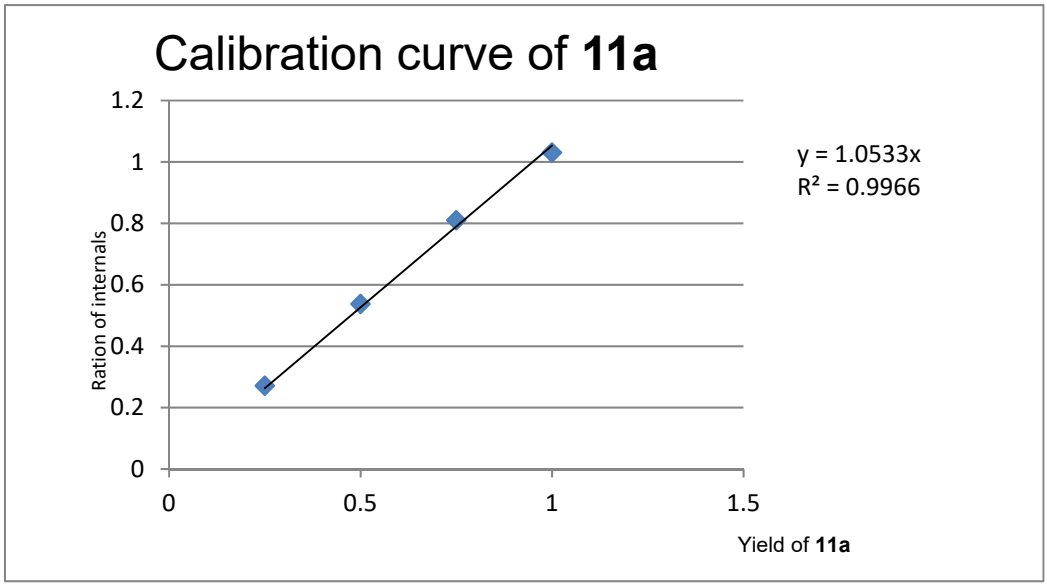
GC-MS chromatograms were acquired for solutions A, B, C and D and in each of them the ratio between the integrals of the signals corresponding to compound **9a** (retention time: 13.8 min) and to the internal standard (retention time: 15.9 min) was calculated. These observed ratios by integration of the chromatogram peaks and the ratios (mmol **9a**/mmol n-decane) were used as the axis of the calibration graph.



Triisopropyl((5-phenylfuran-3-yl)ethynyl)silane **(11a)** (16.2 mg, 0.0500 mmol) was dissolved in CH_2Cl_2 (1.0 mL) (solution P).

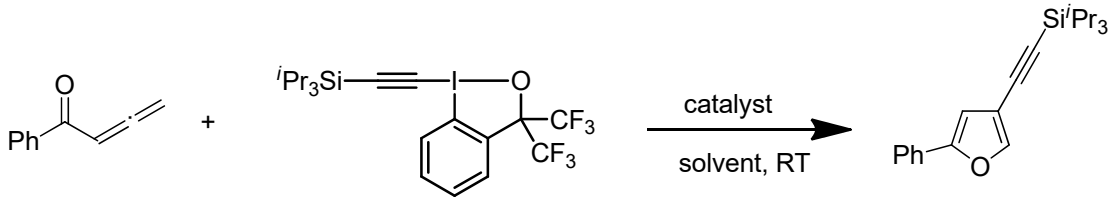
- 25 µL of solution P were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution E;
- 50 µL of solution P were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution F;
- 75 µL of solution P were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution G;
- 100 µL of solution P were mixed with 160 µL of the standard solution 0.125 M and diluted by adding CH_2Cl_2 (600 µL) to obtain solution H;

GC-MS chromatograms were acquired for solutions E, F, G and H and in each of them the ratio between the integrals of the signals corresponding to compound **11a** (retention time: 30.7 min) and to the internal standard (retention time: 15.9 min) was calculated. These observed ratios by integration of the chromatogram peaks and the ratios (mmol **11a**/mmol n-decane) were used as the axis of the calibration graph.



The complete list of experiments for the optimizationof the domino alkynylation with benziodoxole reagent **10** is shown in Table S2:

Table S2: Optimization with bistrifluoromethyl benziodoxole reagent **10**:



9a **10** **11a**

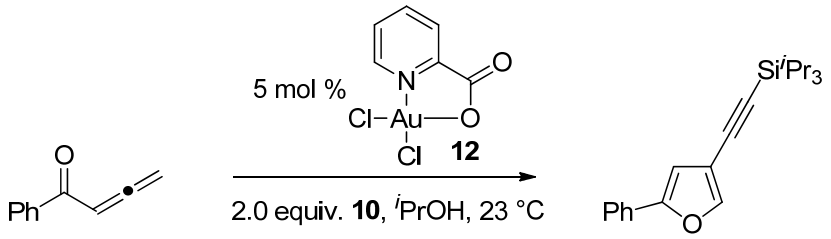
Entry	Catalyst	Base	Solvent	Yield (%)
1	**12**	-	CH_3CN	50[b]
2	**12**	-	CH_3CN	<5
3	**12**	-	CH_3CN	<5
4	**12**	Na_2CO_3	CH_3CN	33
5	**12**	Na_2CO_3	CH_3CN	73
6	**12**	Na_2CO_3	CH_2Cl_2	11
7	**12**	Na_2CO_3	THF	6
8	**12**	Na_2CO_3	EtOH	23
9	**12**	Na_2CO_3	^{i}PrOH	93
10	$AuCl_3$	Na_2CO_3	^{i}PrOH	0
11	$AuCl_3$·Pyridine	Na_2CO_3	^{i}PrOH	0
12	$AuCl_3$+benzoic acid	Na_2CO_3	^{i}PrOH	0
13	$AuCl_3$+isonicotinic acid	Na_2CO_3	^{i}PrOH	0
14	$AuCl_3$·Pyridine+benzoic acid	Na_2CO_3	^{i}PrOH	0
15	$AuCl_3$+ picolinic acid	Na_2CO_3	^{i}PrOH	81

[a] 14 % cyclization product **6g** was obtained.

General procedure for *β* alkynylation reaction:

1-[(Tri*iso*propylsilyl)ethynyl]-3,3-bis(trifluoromethyl)-3(*1H*)-1,2-benziodoxole (**10**) (330 mg, 0.600 mmol, 2.00 equiv)**,** Na_2CO_3 (64 mg, 0.60 mmol, 2.0 equiv) and pyridine-2-carboxylato-gold(III) dichloride (**12**) (5.8 mg, 0.015 mmol, 0.050 equiv) were added into a solution of ketone allene (0.3 mmol, 1 equiv) and *iso*-propanol (15 mL). The reaction was stopped after 72 h, the solution was removed under vaccum, and the crude product was purified by column chromatography directly (SiO_2, Pentane) without any further work-up.

Triisopropyl((5-phenylfuran-3-yl)ethynyl)silane (11a)



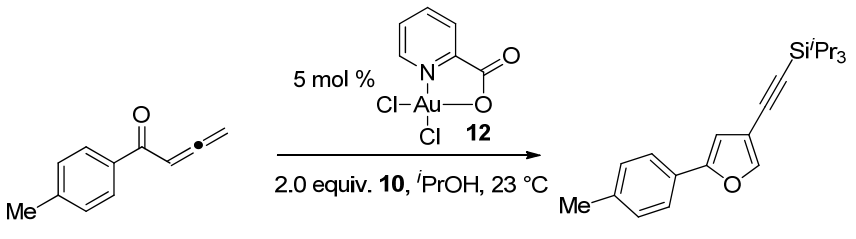
9a **11a**

11a was obtained as yellow oil (66 mg, 0.20 mmol, 68%).

R_f (Pentane): 0.7.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (app d, 3 H, *J* = 8.1 Hz, *ArH* + *FuranH*), 7.39 (t, 2 H, *J* = 7.5 Hz, *ArH*), 7.29 (d, 1 H, *J* = 7.5 Hz, *ArH*), 6.69 (s, 1 H, *FuranH*), 1.12 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.9, 145.6, 130.1, 128.7, 127.9, 123.9, 109.8, 107.8, 97.7, 92.9, 18.6, 11.3. IR 2943 (s), 2923 (m), 2865 (s), 2157 (m), 1746 (w), 1463 (m), 1384 (w), 1253 (w), 1228 (w), 1191 (w), 1144 (m), 1072 (w), 1016 (m), 992 (s), 883 (s), 808 (m). HRMS (ESI) calcd for $C_{21}H_{29}OSi^+$ $[M+H]^+$ 325.1982; found 325.1987.

Triisopropyl((5-(*p*-tolyl)furan-3-yl)ethynyl)silane (11b)



9b **11b**

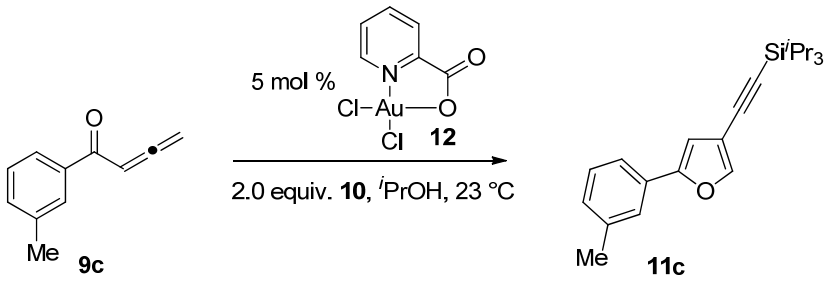
11b was obtained as transparent oil (95 mg, 0.28 mmol, 94%)

R_f (Pentane): 0.4.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (s, 1 H, *FuranH*), 7.54 (d, 2 H, *J* = 8.1 Hz, *ArH*), 7.20 (d, 2 H, *J* = 8.1 Hz, *ArH*), 6.65 (s, 1 H, *FuranH*), 2.37 (s, 3 H, *CH*$_3$), 1.15 (s, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.1, 145.2, 137.8, 129.4, 127.4, 123.9, 109.7, 107.1, 97.9, 92.8, 21.3, 18.7, 11.3. IR 2943 (s), 2892 (m), 2866 (s), 2160 (m), 1539 (w), 1496 (w), 1465 (m),

1385 (w), 1145 (m), 1014 (w), 994 (m), 916 (m), 885 (m), 820 (m), 804 (s), 759 (m). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2140.

Triisopropyl((5-(m-tolyl)furan-3-yl)ethynyl)silane (11c)

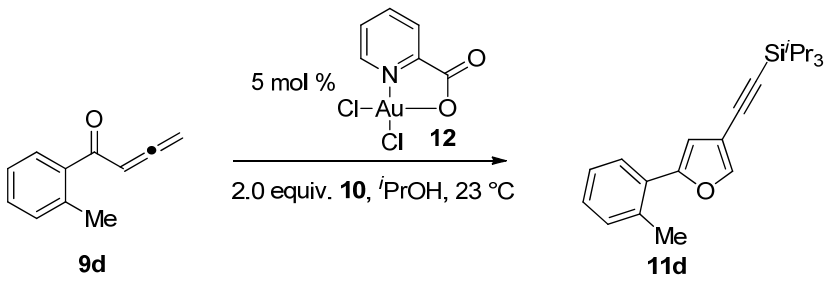


11c was obtained as transparent oil (96.0 mg, 0.28 mmol, 95%).

R_f (Pentane): 0.4.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (s, 1 H, *ArH*), 7.49 (s, 1 H, *FuranH*), 7.46 (d, 1 H, *J* = 8.0 Hz, *ArH*), 7.29 (t, 1 H, *J* = 7.6 Hz, *ArH*), 7.12 (d, 1 H, *J* = 7.5 Hz, *ArH*), 6.70 (s, 1 H, *FuranH*), 2.40 (s, 3 H, *CH₃*), 1.17 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.1, 145.4, 138.3, 130.0, 128.7, 128.6, 124.6, 121.1, 109.7, 107.7, 97.8, 92.8, 21.4, 18.7, 11.3. IR 2943 (s), 2892 (m), 2865 (s), 2362 (w), 2339 (w), 2162 (m), 1723 (w), 1615 (w), 1582 (w), 1464 (m), 1384 (w), 1243 (w), 1144 (m), 993 (s), 928 (m), 883 (s), 809 (m), 786 (s), 756 (s). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2136.

Triisopropyl((5-(o-tolyl)furan-3-yl)ethynyl)silane (11d)

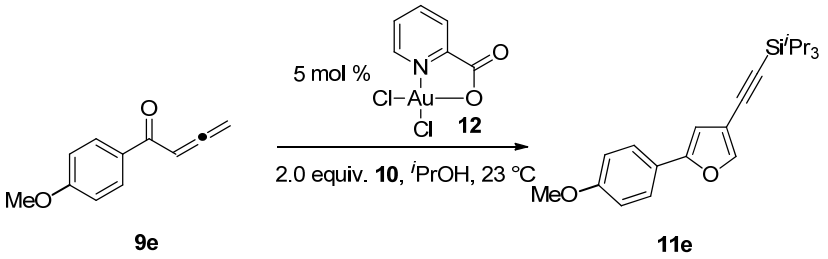


11d was obtained as transparent oil (95.0 mg, 0.28 mmol, 94%)

R_f (Pentane): 0.4.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (s, 1 H, *FuranH*), 7.67 (m, 1 H, *ArH*), 7.27 (m, 3 H, *ArH*), 6.60 (s, 1 H, *FuranH*), 2.51 (s, 3 H, *CH₃*), 1.16 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.5, 145.3, 134.9, 131.1, 129.4, 128.0, 127.2, 126.0, 111.2, 109.4, 97.8, 92.8, 21.8, 18.7, 11.3. IR 2944 (m), 2891 (w), 2865 (m), 2159 (m), 1932 (w), 1657 (w), 1463 (m), 1150 (w), 1013 (w), 994 (m), 913 (m), 884 (m), 812 (w), 758 (s), 736 (s). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2149.

Triisopropyl((5-(4-methoxyphenyl)furan-3-yl)ethynyl)silane (11e)

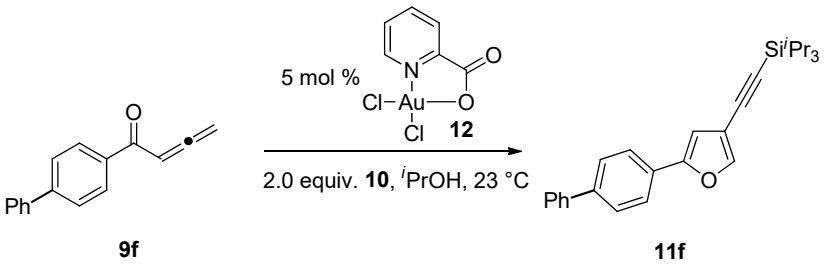


11e was obtained as yellow oil (88 mg, 0.25 mmol, 83%).

R_f (Pentane/Et_2O 100/1): 0.3.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (s, 1 H, *FuranH*), 7.57 (d, *J* = 8.8 Hz, *ArH*), 6.92 (d, *J* = 8.8 Hz, *ArH*), 6.56 (s, 1 H, *FuranH*), 3.83 (s, 3 H, OCH_3), 1.14 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 159.4, 154.0, 145.0, 125.4, 123.1, 114.2, 109.7, 106.2, 97.9, 92.7, 55.3, 18.6, 11.3. IR 2944 (m), 2865 (m), 2360 (w), 2159 (w), 1618 (w), 1497 (m), 1465 (m), 1298 (w), 1253 (s), 1178 (m), 1144 (w), 1041 (w), 1021 (w), 993 (m), 916 (w), 885 (w), 834 (m), 801 (m), 758 (w). HRMS (ESI) calcd for $C_{22}H_{31}O_2Si^+$ $[M+H]^+$ 355.2088; found 355.2083.

((5-([1,1'-Biphenyl]-4-yl)furan-3-yl)ethynyl)triisopropylsilane (11f)

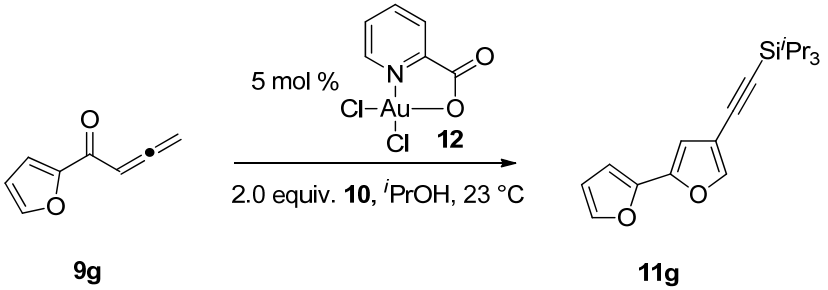


11f was obtained as yellow solid (64 mg, 0.16 mmol, 53%).

R_f (Pentane): 0.3. Mp 127 – 128°C.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (m, 3 H, *ArH*), 7.62 (m, 4 H, *ArH* + *Furan H*), 7.45 (t, 2 H, *J* = 7.4 Hz, *ArH*), 7.37 (d, 1 H, *J* = 7.4 Hz, *ArH*), 6.73 (s, 1 H, *Furan H*), 1.14 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.7, 145.6, 140.6, 140.4, 129.0, 128.8, 127.5, 127.4, 126.9, 124.3, 109.9, 108.0, 97.6, 93.0, 18.7, 11.3. IR 2945 (w), 2866 (w), 2361 (w), 1962 (w), 1932 (w), 1651 (w), 1604 (w), 1485 (w), 1417 (w), 1349 (w), 1281 (w), 1221 (w), 910 (s), 849 (w), 735 (s). HRMS (ESI) calcd for $C_{27}H_{33}OSi^+$ $[M+H]^+$ 401.2295; found 401.2294.

([2,2'-Bifuran]-4-ylethynyl)triisopropylsilane (11g)

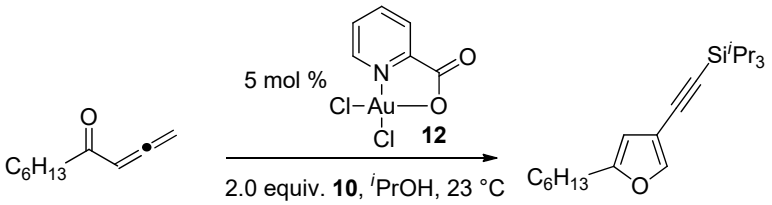


11g was obtained as transparent oil (71 mg, 0.22 mmol, 75%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (s, 1 H, *Furan H*), 7.42 (br s, 1 H, *Furan H*), 6.59 (s, 1 H, *Furan H*), 6.57 (d, 1 H, *J* = 3.3 Hz, *Furan H*), 6.45 (dd, 1 H, *J* = 3.3, 1.8 Hz, *Furan H*), 1.11 (m, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.4, 145.7, 145.1, 142.2, 111.4, 109.6, 107.8, 106.0, 97.2, 93.2, 18.6, 11.3. IR 2949 (s), 2868 (s), 2362 (w), 2336 (w), 2164 (m), 1464 (m), 1178 (w), 1143 (w), 1072 (w), 1002 (s), 884 (s), 806 (m), 752 (s), 740 (s). HRMS (ESI) calcd for $C_{19}H_{27}O_2Si^+$ $[M+H]^+$ 315.1775; found 315.1766.

((5-Hexylfuran-3-yl)ethynyl)triisopropylsilane (11h)

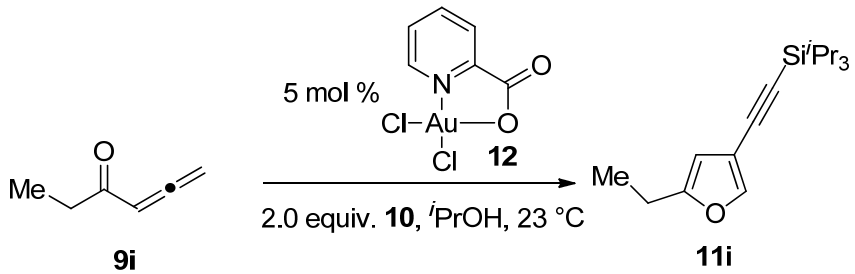


11h was obtained as yellow oil (93 mg, 0.28 mmol, 93%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (s, 1 H, *Furan H*), 6.05 (s, 1 H, *Furan H*), 2.57 (t, 2 H, *J* = 7.5 Hz, *HexylH*), 1.61 (m, 2 H, *HexylH*), 1.33 (m, 6 H, *HexylH*), 1.12 (s, 21 H, *TIPS*), 0.90 (m, 3 H, *HexylH*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.7, 144.6, 108.2, 107.8, 98.5, 91.9, 31.6, 28.8, 27.8, 27.7, 22.6, 18.6, 14.1, 11.3. IR 2941 (s), 2865 (s), 2162 (m), 1601 (w), 1465 (m), 1383 (w), 1367 (w), 1346 (w), 1333 (w), 1277 (w), 1146 (m), 1073 (w), 1015 (w), 991 (m), 925 (w), 884 (s), 805 (m), 770 (w), 761 (w), 715 (w). HRMS (ESI) calcd for $C_{21}H_{37}OSi^+$ $[M+H]^+$ 333.2608; found 333.2613.

((5-Ethylfuran-3-yl)ethynyl)triisopropylsilane (11i)

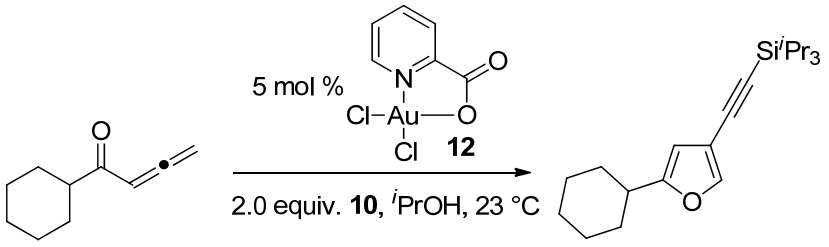


11i was obtained as yellow oil (80 mg, 0.29 mmol, 96%).

R_f (Pentane): 0.7.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (s, 1 H, *J* = 1.0 Hz, *Furan H*), 6.06 (dd, 1 H, *J* = 1.0, 1.0 Hz, *Furan H*), 2.61 (qd, 2 H, *J* = 7.5, 1.0 Hz, *CH_2*), 1.22 (t, 3 H, *J* = 7.5 Hz, *CH_3*), 1.12 (s, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.9, 144.5, 108.2, 107.2, 98.4, 91.9, 21.2, 18.6, 11.9, 11.3. IR 2943 (s), 2893 (m), 2866 (s), 2361 (m), 2339 (w), 2162 (s), 1602 (w), 1464 (m), 1385 (w), 1325 (w), 1280 (w), 1256 (w), 1148 (s), 1071 (w), 1016 (w), 994 (m), 922 (s), 884 (s), 810 (m), 766 (s), 737 (m). HRMS (ESI) calcd for $C_{17}H_{29}OSi^+$ $[M+H]^+$ 277.1982; found 277.1976.

((5-Cyclohexylfuran-3-yl)ethynyl)triisopropylsilane (11j)

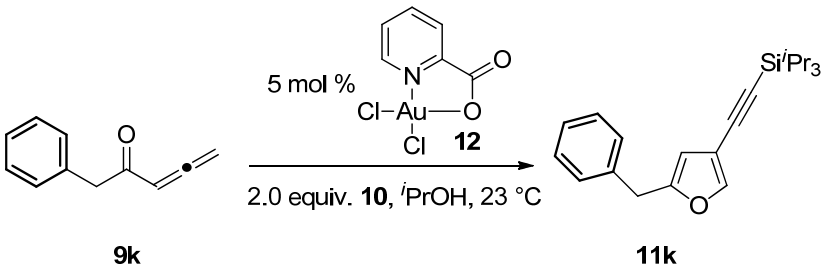


11j was obtained as transparent oil (96 mg, 0.29 mmol, 97%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (s, 1 H, *Furan H*), 6.03 (s, 1 H, *Furan H*), 2.58 (m, 1 H, *cyclohexylH*), 1.99 (d, 2 H, *J* = 7.5 Hz, *cyclohexylH*), 1.74 (m, 3 H, *cyclohexylH*), 1.32 (m, 5 H, *cyclohexylH*), 1.12 (s, 21 H. *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.0, 144.3, 108.0, 106.0, 98.6, 91.8, 37.0, 31.3, 26.0, 25.8, 18.6, 11.3. IR 2932 (s), 2863 (s), 2162 (m), 1725 (w), 1597 (w), 1494 (w), 1464 (m), 1385 (w), 1367 (w), 1343 (w), 1308 (w), 1265 (w), 1168 (w), 1144 (m), 1122 (w), 1073 (w), 992 (m), 938 (w), 920 (w), 884 (s), 857 (w), 806 (m), 768 (m), 734 (s). HRMS (ESI) calcd for $C_{21}H_{35}OSi^+$ $[M+H]^+$ 331.2452; found 331.2441.

((5-Benzylfuran-3-yl)ethynyl)triisopropylsilane (11k)

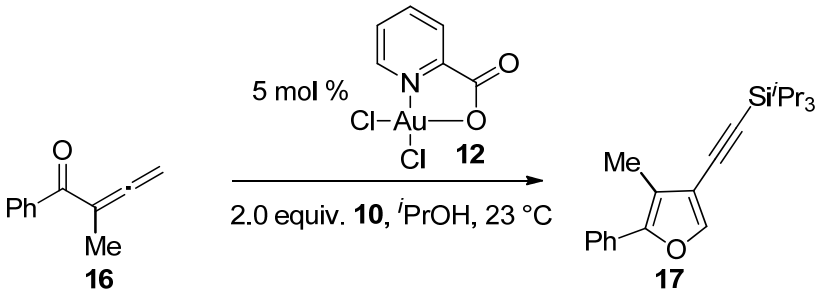


11k was obtained as transparent oil (78 mg, 0.23 mmol, 77%).

R_f (Pentane): 0.6.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (s, 1 H, *Furan H*), 7.29 (m, 2 H, *ArH*), 7.21 (m, 3 H, *ArH*), 6.04 (s, 1 H, *Furan H*), 3.90 (s, 2 H, *CH*$_2$Ph), 1.09 (s, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.8, 145.3, 137.3, 128.7, 128.6, 126.7, 109.4, 108.4, 98.1, 92.2, 34.3, 18.6, 11.3. IR 2943 (s), 2865 (s), 2162 (s), 1600 (w), 1496 (w), 1462 (m), 1142 (m), 1074 (w), 1016 (w), 989 (m), 951 (w), 884 (s), 809 (w), 784 (w), 755 (w), 706 (s). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2133.

Triisopropyl((4-methyl-5-phenylfuran-3-yl)ethynyl)silane (16)

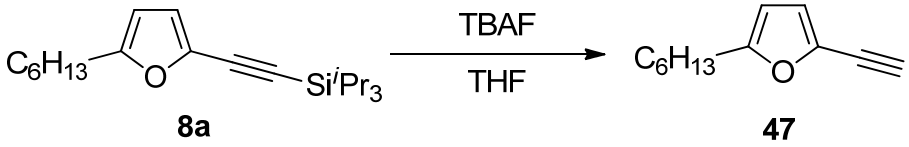


16 was obtained as yellow oil (95 mg, 0.28 mmol, 94%).

R_f (Pentane): 0.7.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (m, 3 H, *ArH + Furan H*), 7.44 (t, 2 H, *J* = 7.5 Hz, *ArH*), 7.31 (t, 1 H, *J* = 7.5 Hz, *ArH*), 2.33 (s, 3 H, *CH*$_3$), 1.17 (s, 21 H, *TIPS*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 148.8, 144.0, 131.2, 128.6, 127.2, 125.4, 117.9, 112.4, 97.2, 94.9, 18.7, 11.3, 10.2. IR 2952 (s), 2870 (s), 2360 (s), 2160 (w), 1781 (s), 1461 (m), 1385 (w), 1254 (w), 1122 (w), 1064 (w), 1002 (m), 960 (w), 884 (m), 767 (w). HRMS (ESI) calcd for $C_{22}H_{31}OSi^+$ $[M+H]^+$ 339.2139; found 339.2136. The substitution pattern was confirmed by 2D NMR experiment.

2-Ethynyl-5-hexylfuran (47)

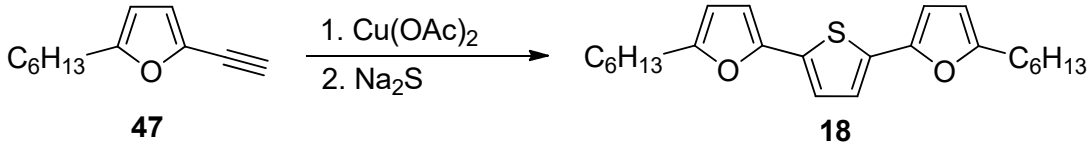


TBAF (1 M in THF, 0.48 mL, 0.48 mmol, 1.2 equiv) was added into a solution of **8a** (133 mg, 0.400 mmol, 1.0 equiv) and dry THF (5 mL) at 0 °C. A saturated solution of NH_4Cl (20 mL) was added into the solution after 1 h. The aqueous layer was extracted with Et_2O (3 x 10 mL). The combined organic layers were dried with MgSO4 and concentrated under reduced pressure. The resulting oil was purified by flash chromatography (pentane) to afford **47** (55 mg, 0.31 mmol, 78 %) as colorless oil.

R_f (Pentane): 0.4.

^{1}H NMR (400 MHz, $CDCl_3$) δ 6.55 (d, 1 H, *J* = 3.3, furanH), 5.96 (dt, 1 H, *J* = 3.3, 0.8 Hz, *furanH*), 3.39 (s, 1 H, *CH*), 2.60 (t, 2 H, *J* = 7.6 Hz, alkylH), 1.64 (m, 2 H, alkylH), 1.31 (m, 6 H, alkylH), 0.89 (m, 3 H, *CH*$_3$). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.4, 134.3, 117.1, 106.0, 81.3, 74.5, 31.5, 28.8, 28.2, 27.8, 22.5, 14.0. IR 3902 (w), 3869 (w), 3855 (w), 3838 (w), 3820 (w), 3802 (w), 3748 (w), 3736 (w), 3711 (w), 3690 (w), 3674 (w), 3650 (w), 3629 (w), 3615 (w), 3297 (w), 2958 (w), 2930 (w), 2859 (w), 2361 (s), 2339 (s), 1748 (w), 1735 (w), 1717 (w), 1700 (w), 1684 (w), 1673 (w), 1652 (w), 1637 (w), 1559 (w), 1541 (w), 1523 (m), 1509 (w), 1471 (w), 1459 (w), 1075 (w), 1018 (w), 790 (w). HRMS (ESI) calcd for $C_{12}H_{17}O^+$ $[M+H]^+$ 177.1274; found 177.1271.

2,5-Bis(5-hexylfuran-2-yl)thiophene (18)

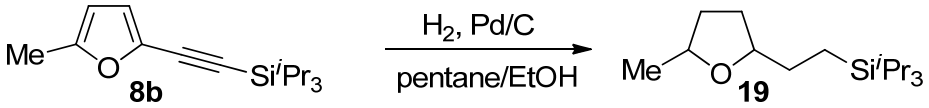


A mixture of **47** (34 mg, 0.20 mmol, 1 equiv) and $Cu(OAc)_2$ (72 mg, 0.40 mmol, 2 equiv) were stirred at 80 °C overnight in CH_3CN (2 mL) under air. The reaction was cooled down and $Na_2S•3H_2O$ (106 mg, 0.400 mmol, 4 equiv) was added. The reaction was stirred at 80 °C for 24 h. The suspension was filtered and the solid was washed with DCM (10 mL). The organic layer was then washed twice with 0.1 M NaOH (10 mL), dried over $MgSO_4$, filtered and concentrated under reduced pressure. The resulting oil was purified by flash chromatography (pentane) to afford **18** (25 mg, 0.065 mmol, 65 %) as yellow oil.

R_f (pentane): 0.5.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (s, 2 H, *thiophenH*), 6.38 (d, 2 H, *J* = 3.2 Hz, *furanH*), 6.02 (d, 2 H, *J* = 3.1 Hz, *furanH*), 2.65 (t, 4 H, *J* = 7.6 Hz, *alkylH*), 1.67 (m, 4 H, *alkylH*), 1.42-1.20 (br m, 12 H. *alkylH*), 0.90 (t, 6 H, *J* = 7.0 Hz, *CH₃*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.2, 147.4, 132.0, 122.0, 106.9, 105.7, 31.6, 28.9, 28.1, 28.0, 22.6, 14.1. IR 2930 (s), 2862 (m), 2362 (m), 2339 (w), 2091 (w), 1464 (w), 1438 (w), 1017 (w), 999 (w), 981 (w), 965 (w), 941 (w), 929 (w), 885 (w), 857 (w), 778 (m), 752 (w), 733 (m). HRMS (ESI) calcd for $C_{24}H_{32}O_2S^+$ $[M]^+$ 384.2118; found 384.2118.

Triisopropyl(2-((2S,5S)-5-methyltetrahydrofuran-2-yl)ethyl)silane (**19**)



A 25 mL flask was charged with Pd/C (10% wt, 16 mg, 0.015 mmol, 0.1 equiv) and a solution of **8b** (39 mg, 0.15 mmol, 1.0 equiv) in pentane/EtOH (2.0 mL / 2.0 mL). The mixture was purged by H_2 during 15 minutes and stirred overnight. The mixture was filtered though a plug of celite to afford **19** (30 mg, 0.11 mmol, 74%) as colorless oil with 5:1 dr according to the ^{1}H NMR.[26]

^{1}H NMR (400 MHz, $CDCl_3$, major diastereomer) δ 3.93 (m, 1 H, *CHO*), 3.71 (m, 1 H, *CHO*), 2.22-1.35 (m, 6 H, *alkylH*), 1.22 (d, 3 H, *J* = 6.0 Hz, *CH₃*), 1.02 (m, 21 H, *TIPS*), 0.56 (m, 2 H, Si*CH₂*). ^{13}C NMR (101 MHz, $CDCl_3$) δ 82.5, 75.2, 32.8, 30.8, 21.4, 18.9, 18.8, 10.9, 5.1. IR 2963 (s), 2941 (s), 2891 (m), 2866 (s), 2359 (w), 2340 (w), 1464 (m), 1384 (w), 1097 (w), 1075 (w), 1013 (w), 919 (w), 883 (s), 739 (m). HRMS (ESI) calcd for $C_{16}H_{35}OSi^+$ $[M+H]^+$ 271.2452; found 271.2448.

6. Spectra of New Compounds:

[25] The peak at 3.93 ppm and 3.71 ppm were used to calculate the DR

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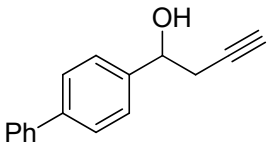
Frequency: 400. 13MHz



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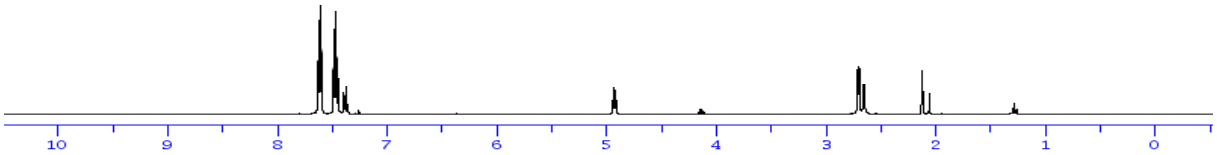

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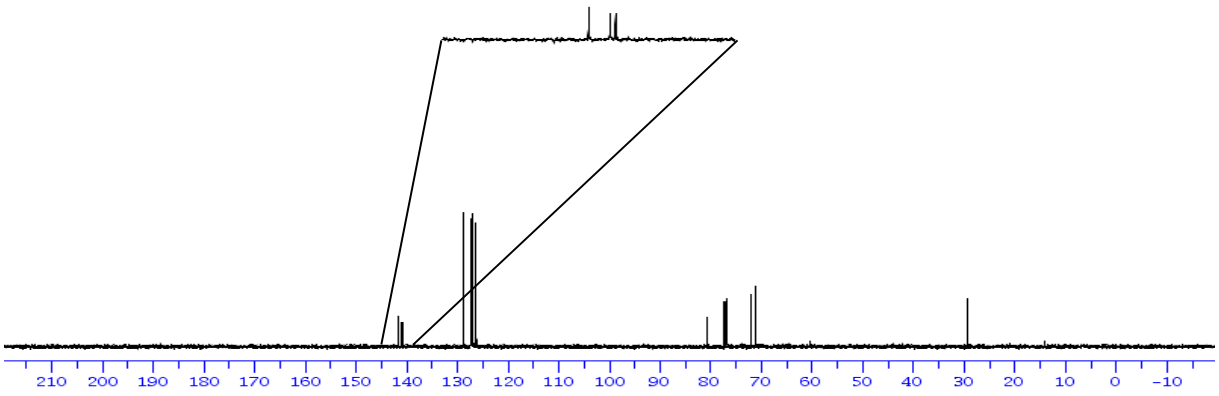

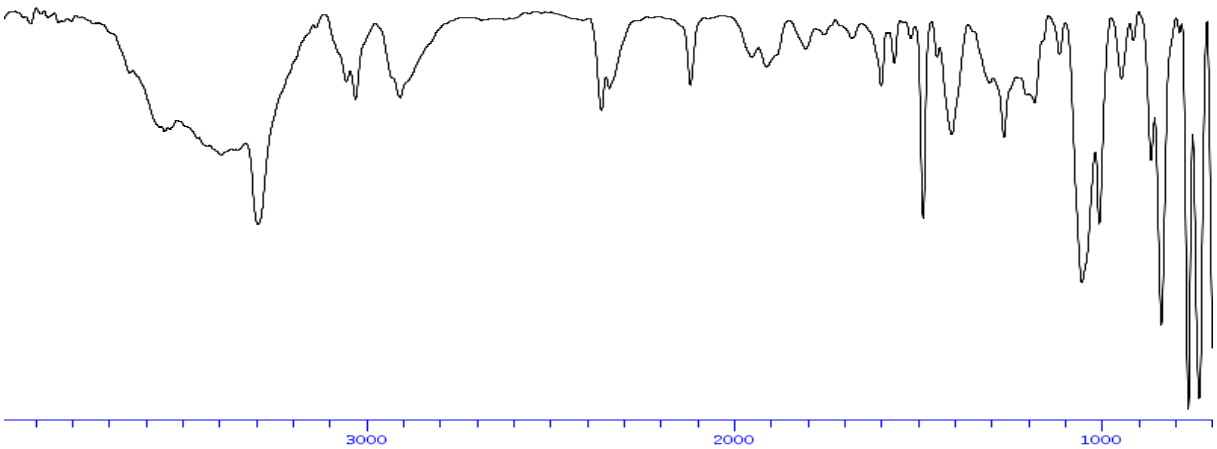

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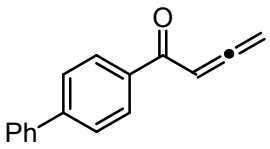

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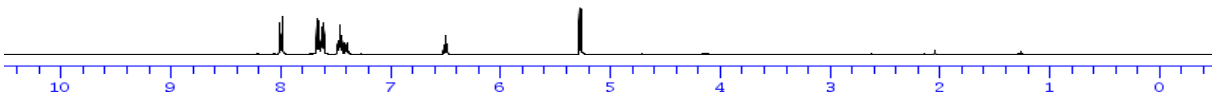

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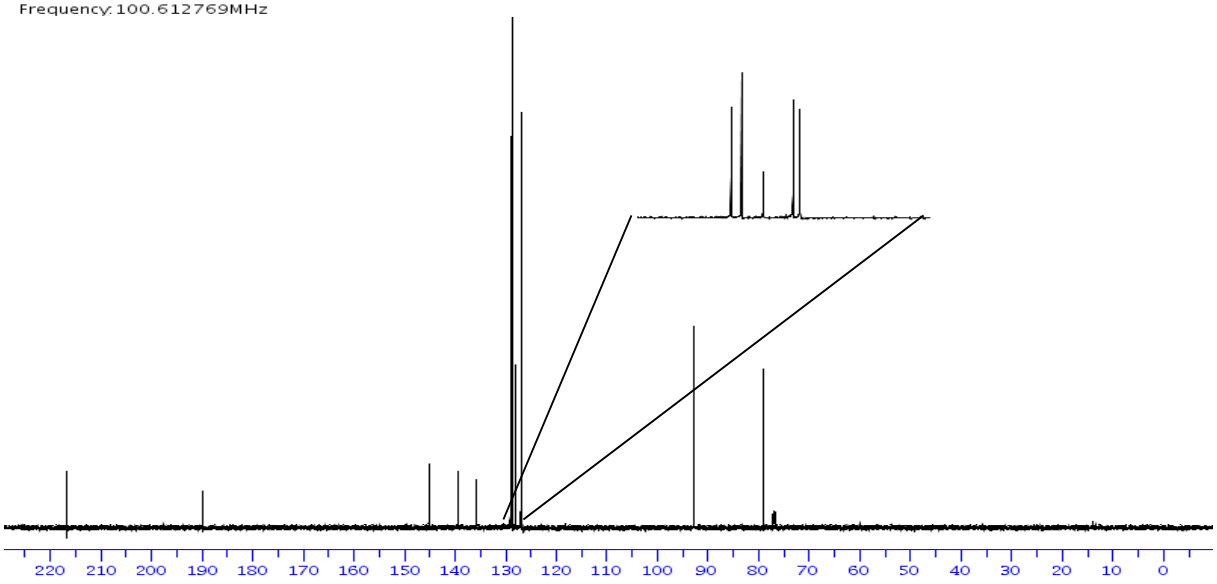

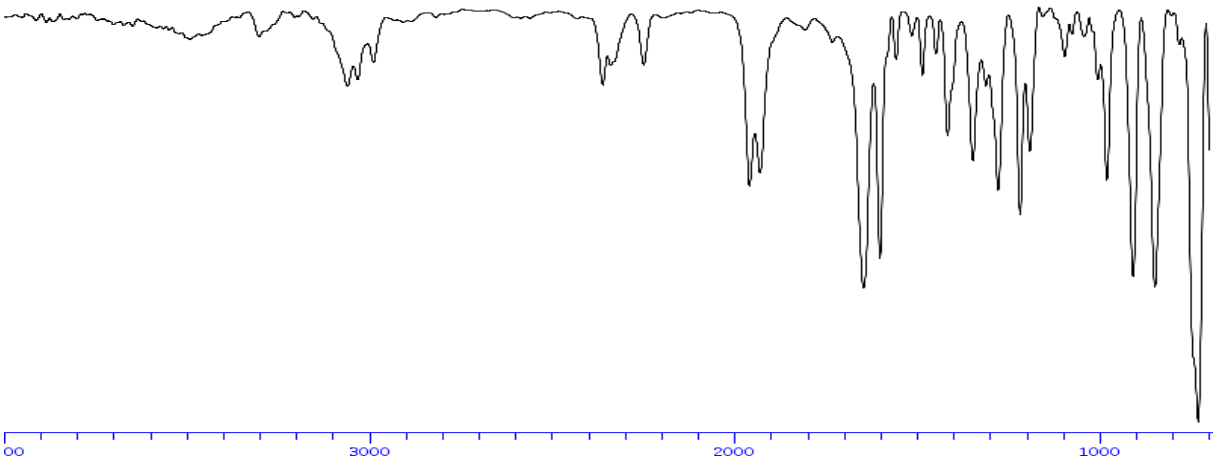

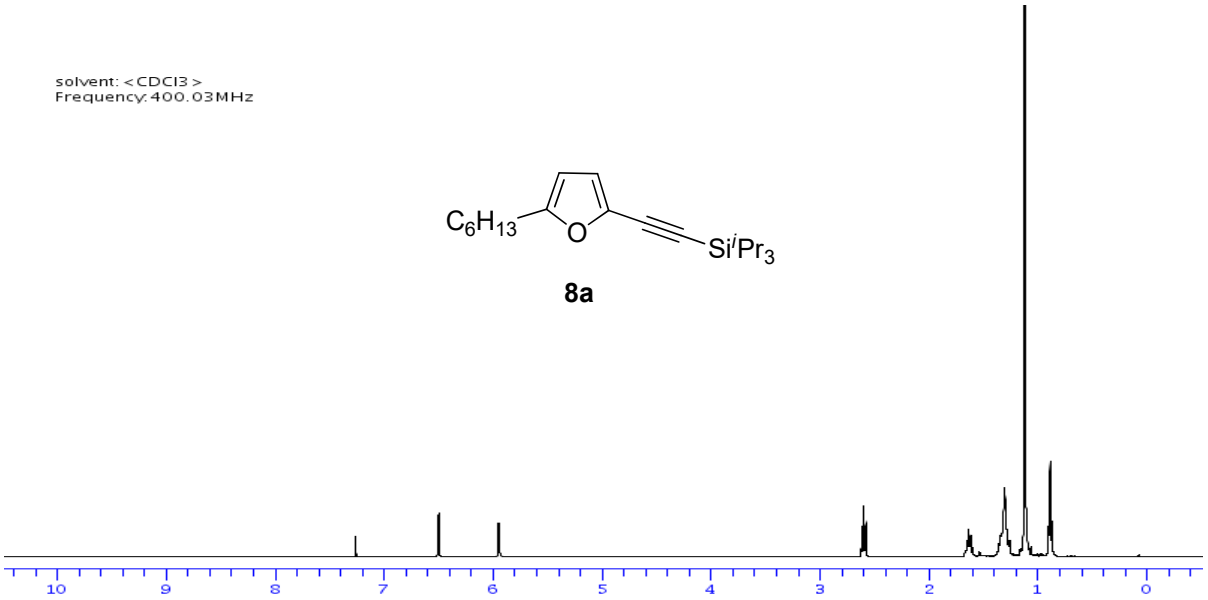
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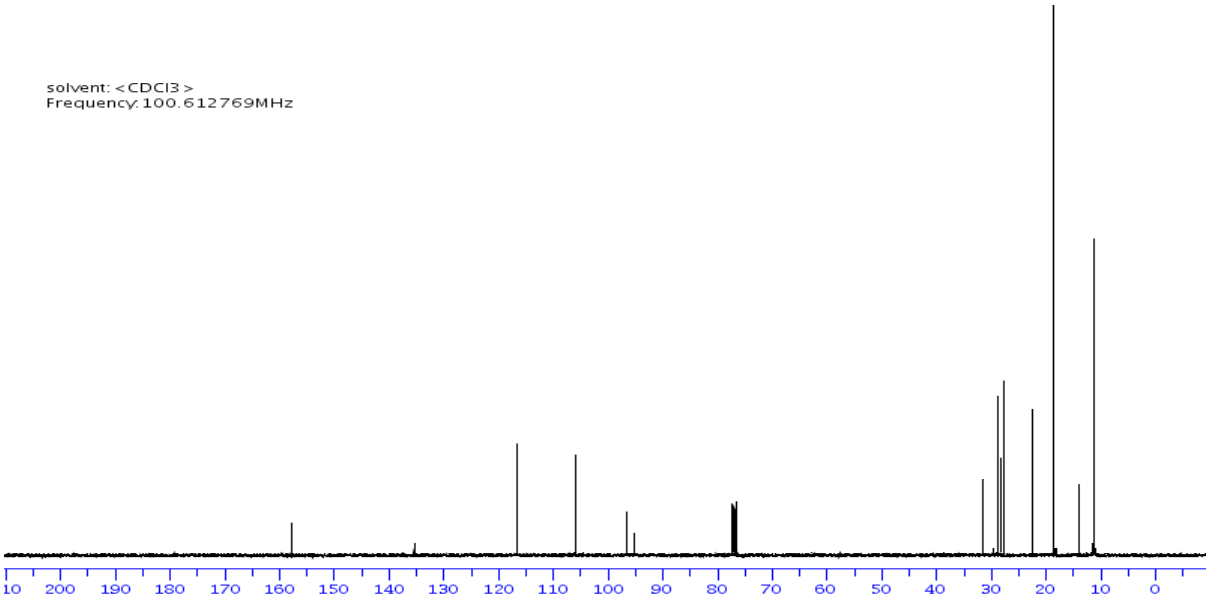
8a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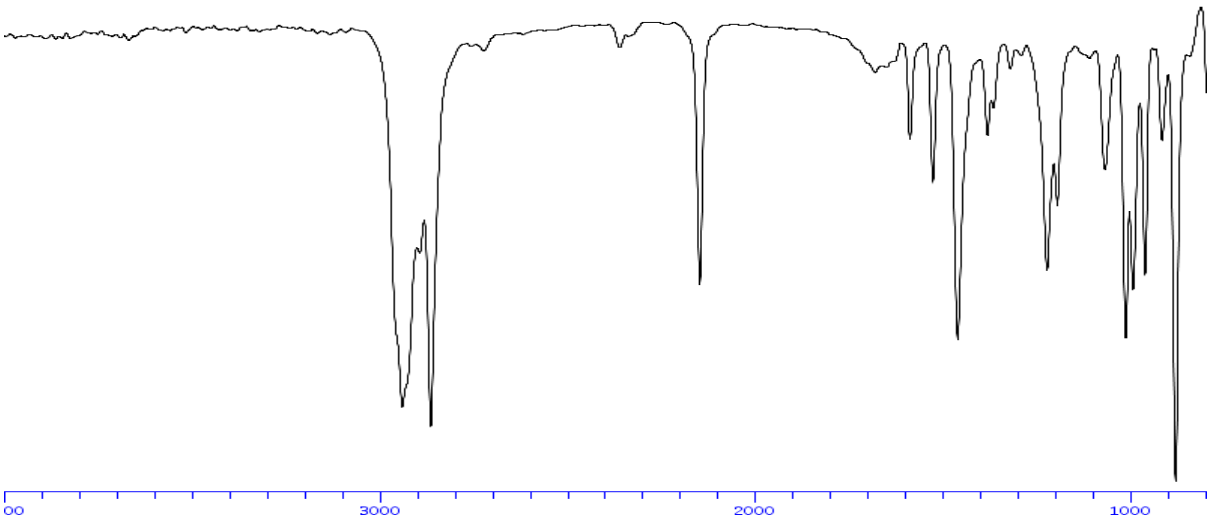
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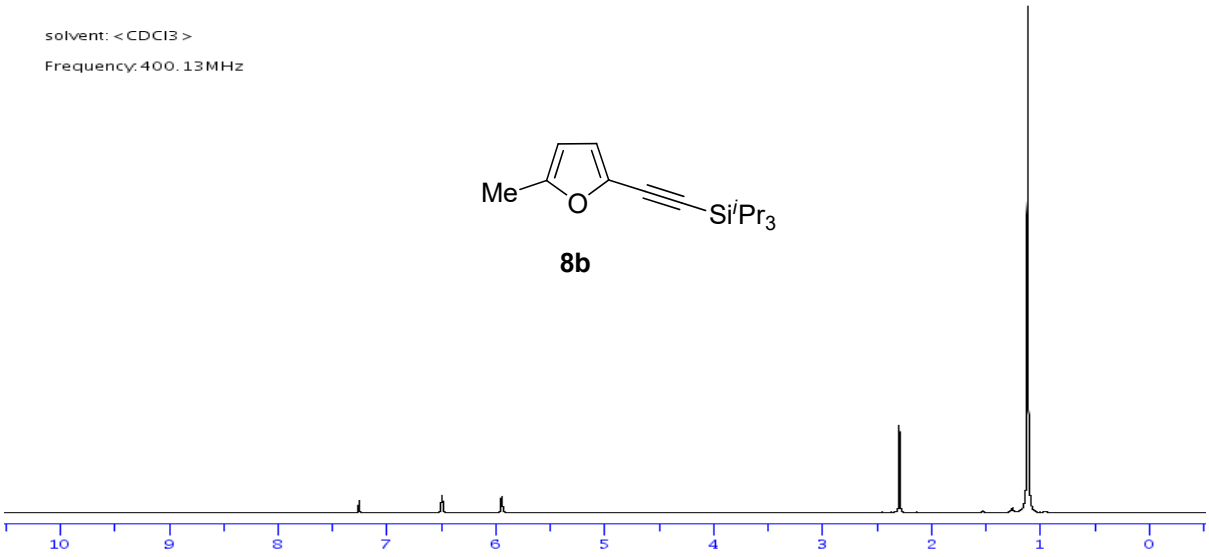
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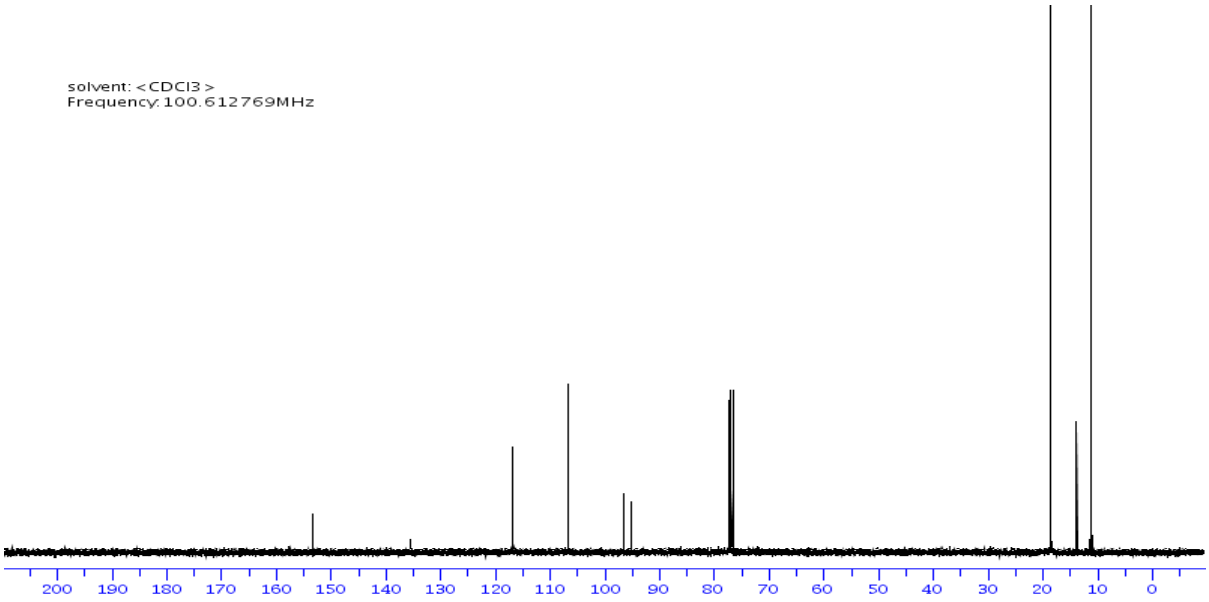
8b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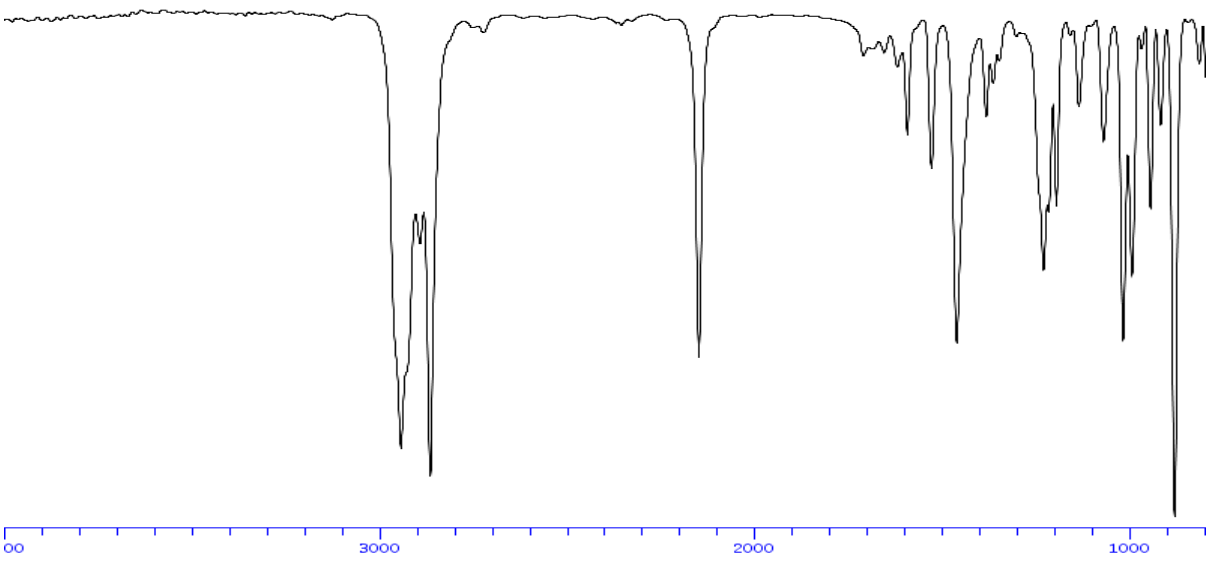
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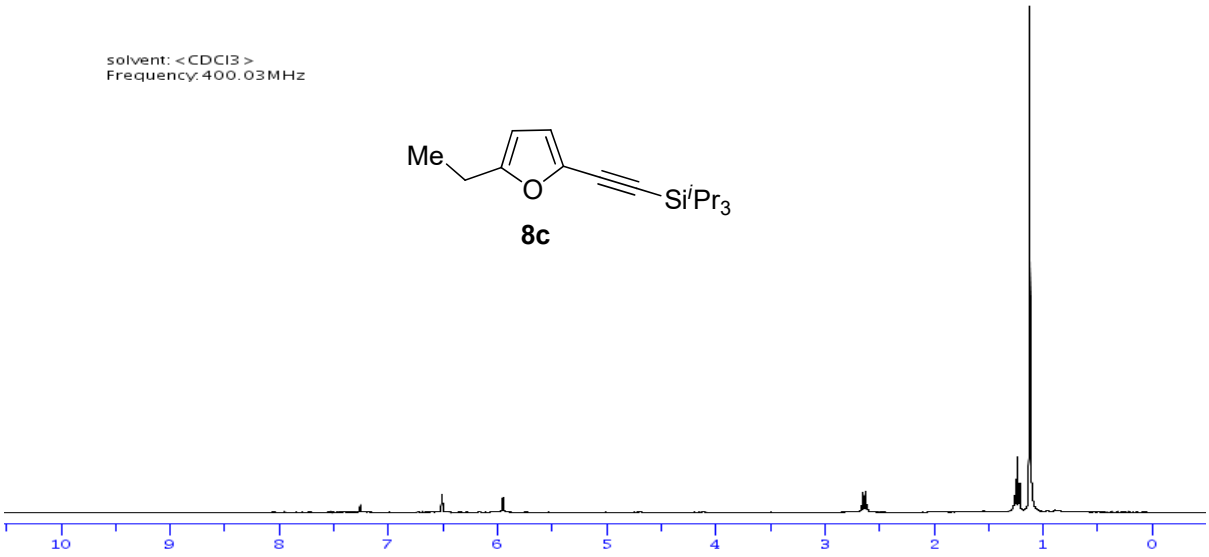
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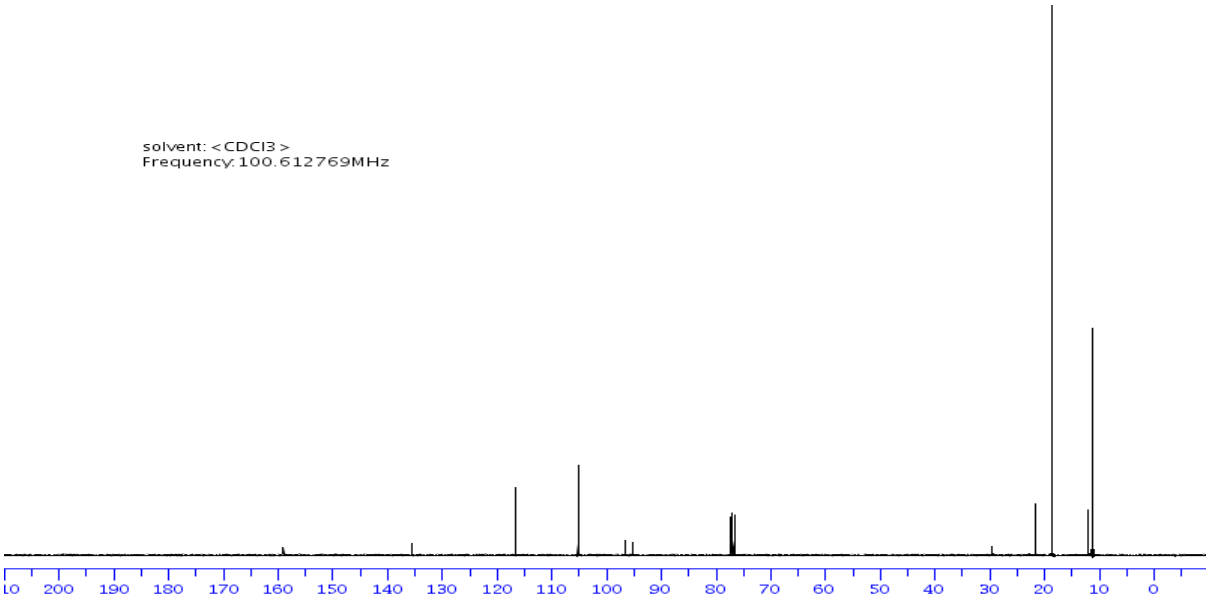
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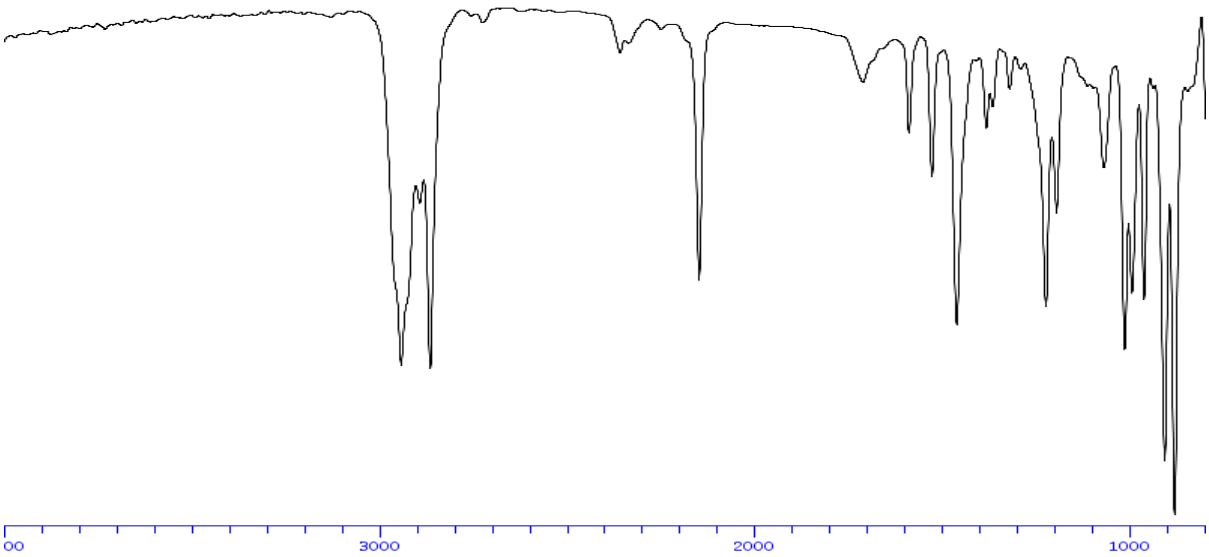
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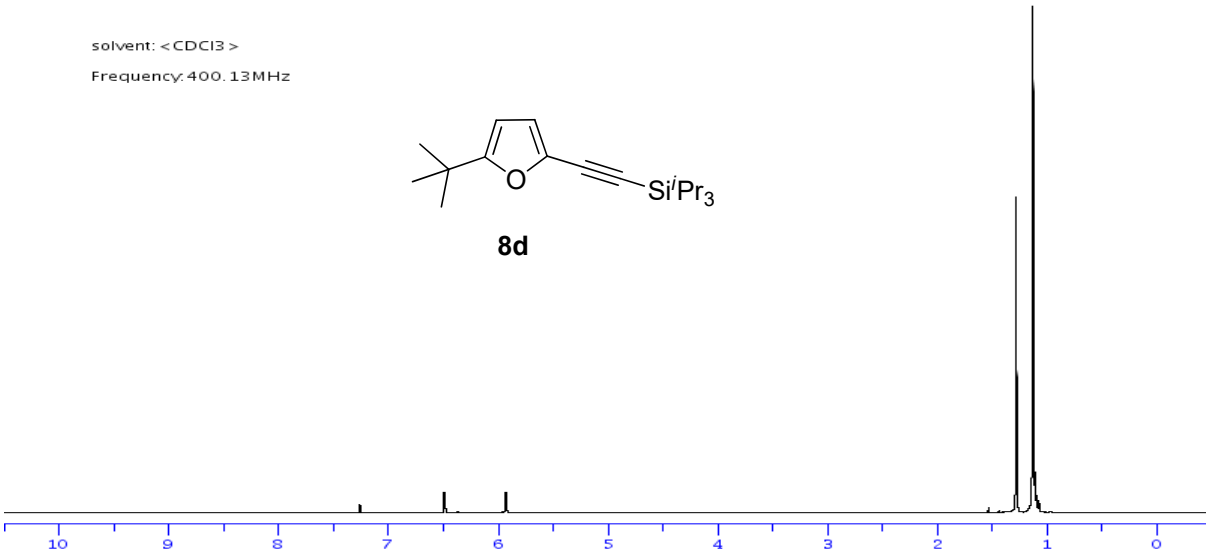
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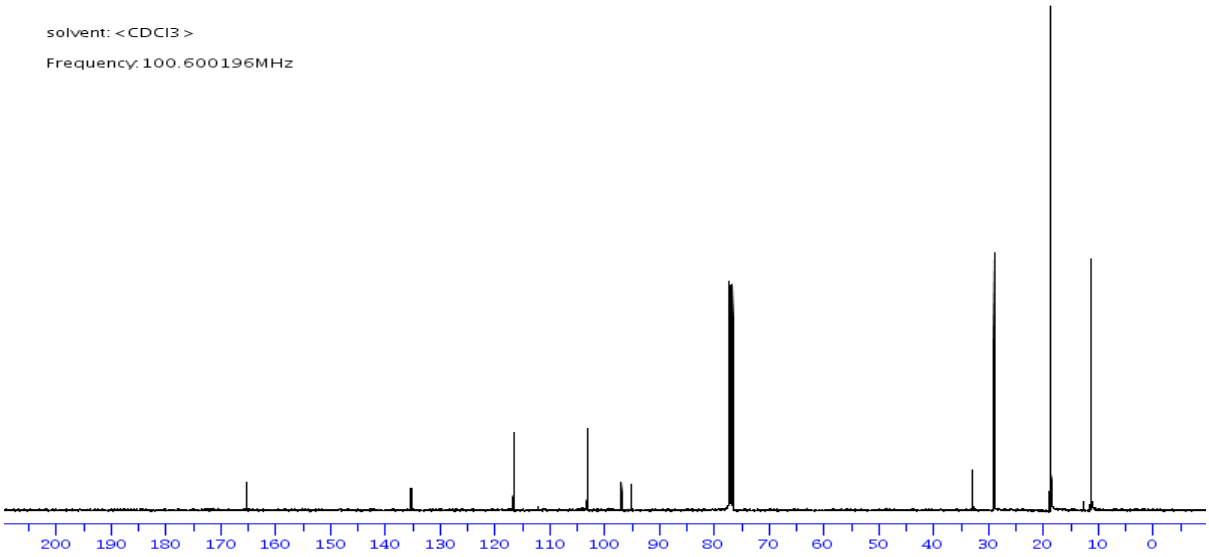
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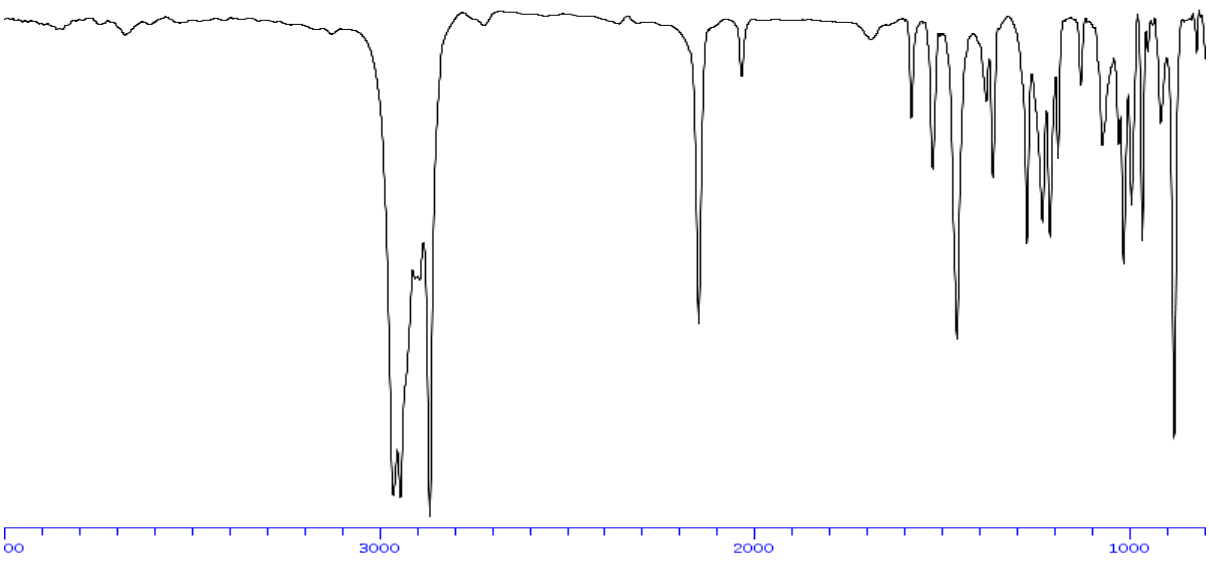
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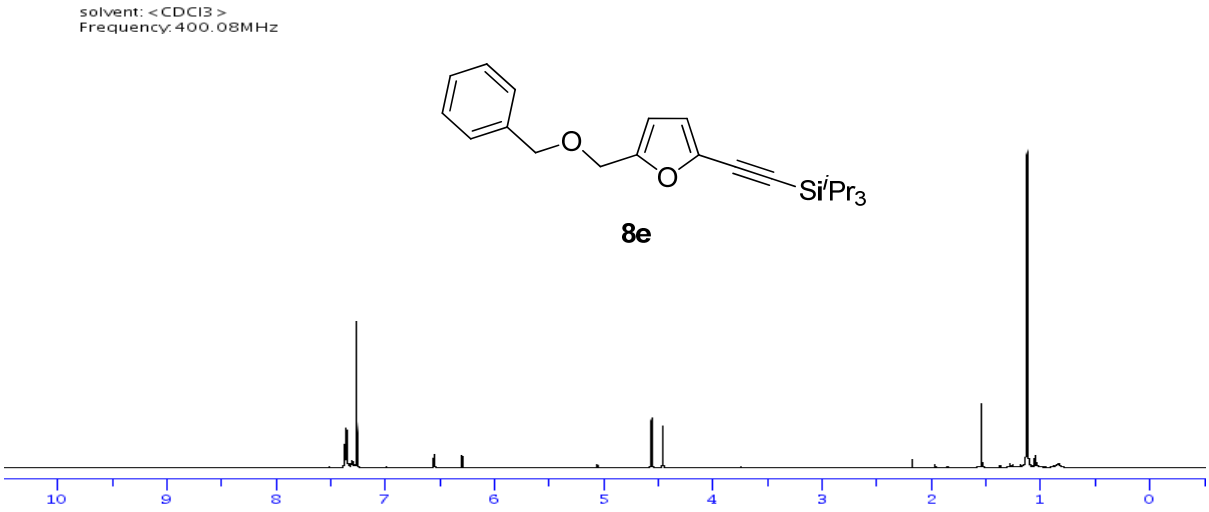
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O
Si^{i}Pr$_3$
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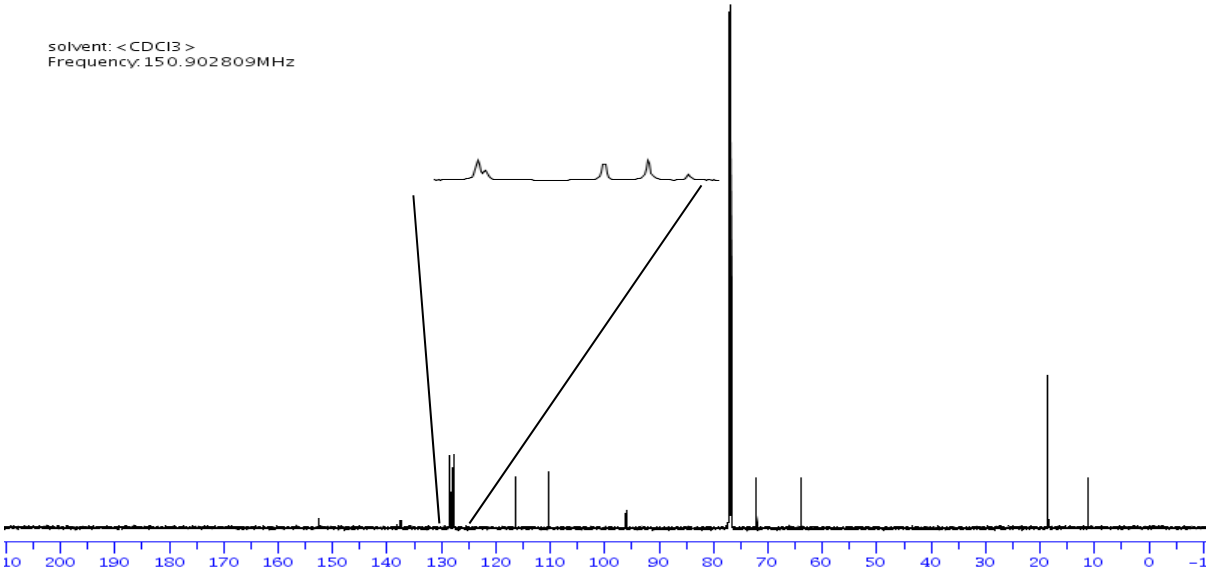
8e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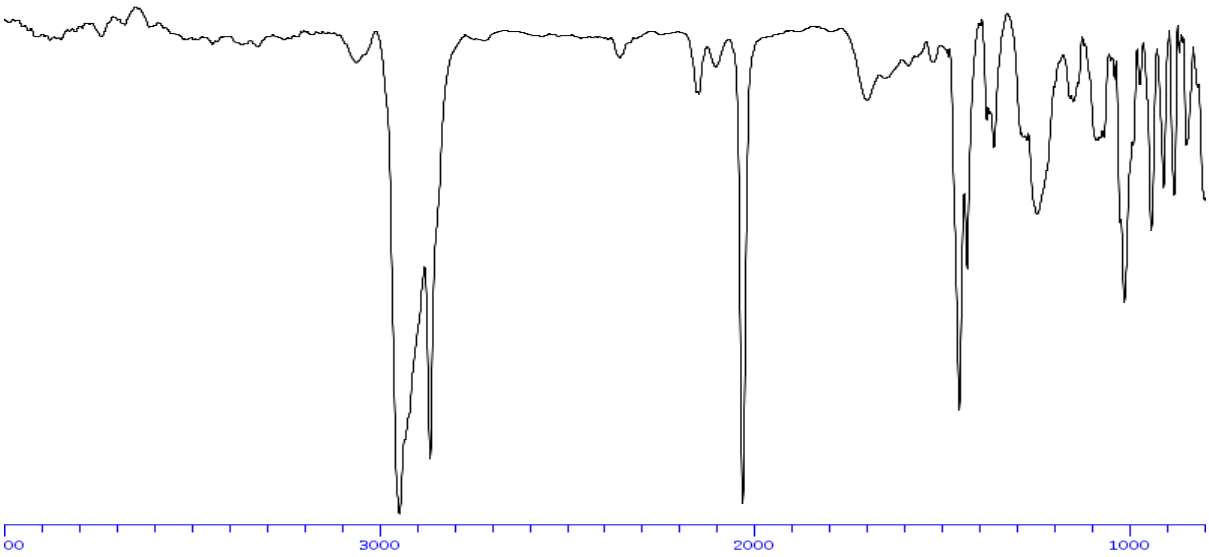
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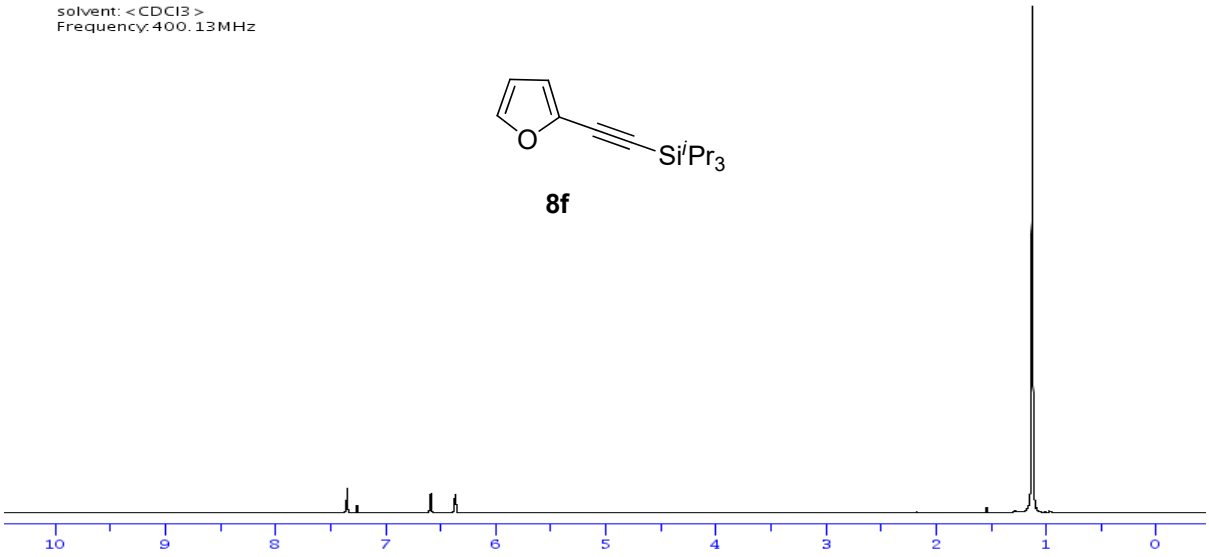
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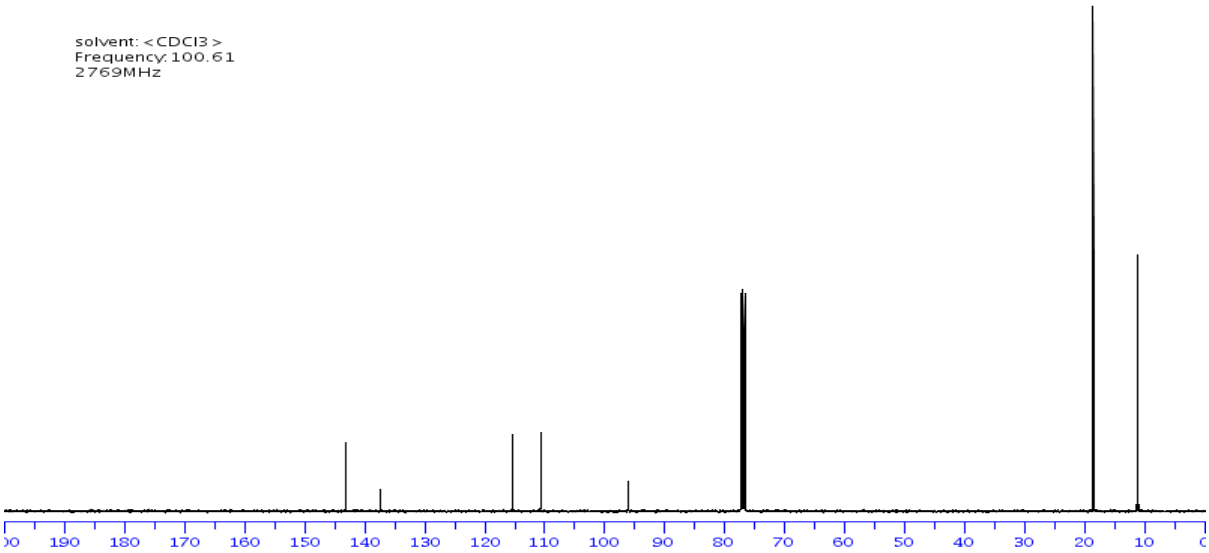
8f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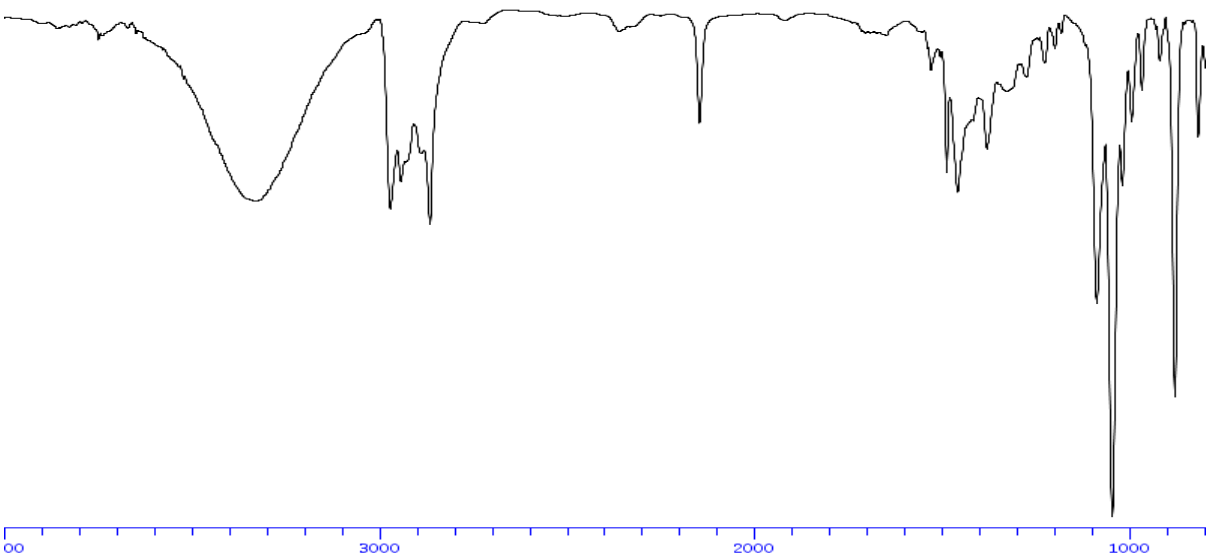
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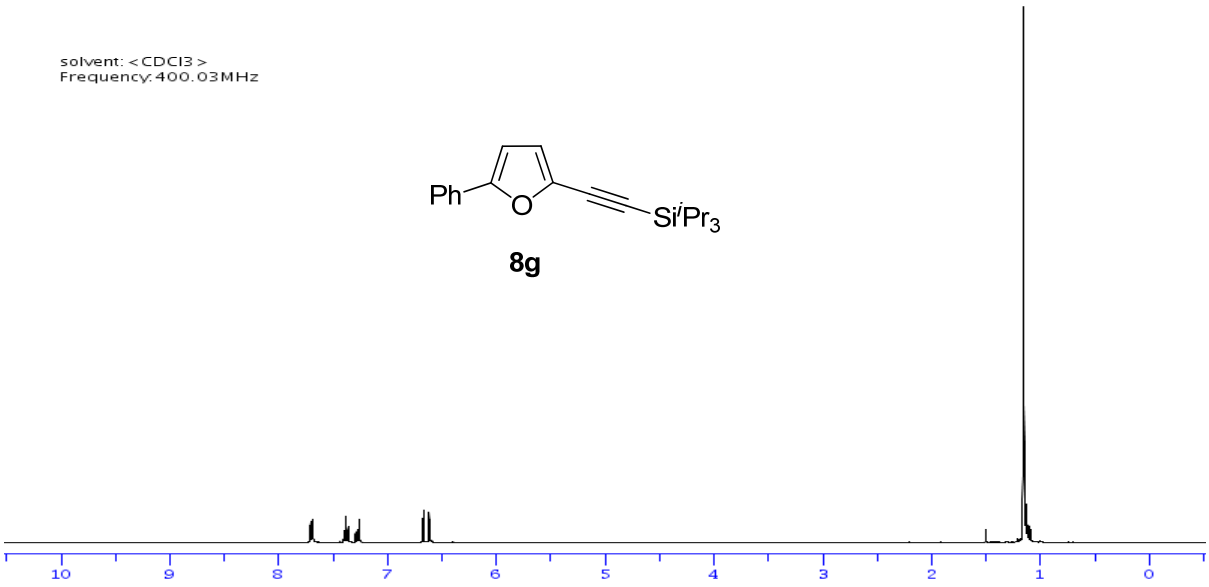
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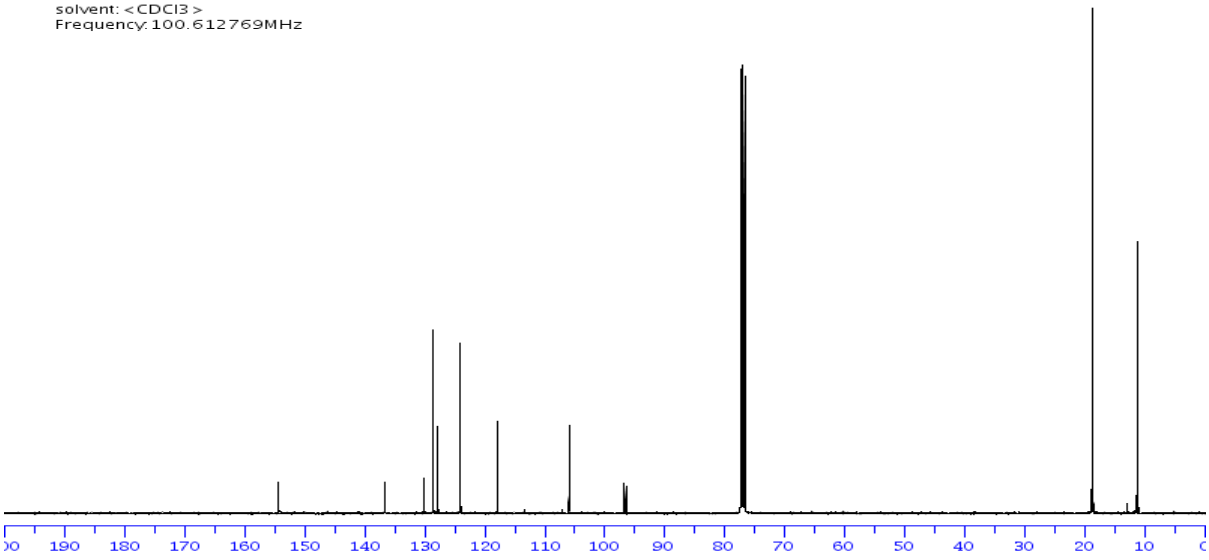
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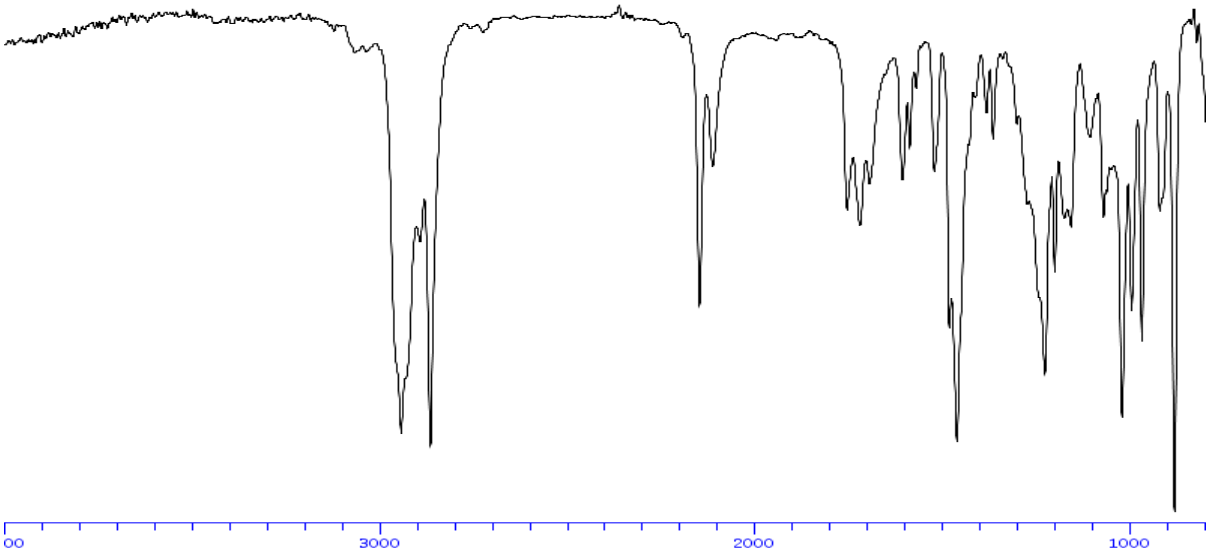
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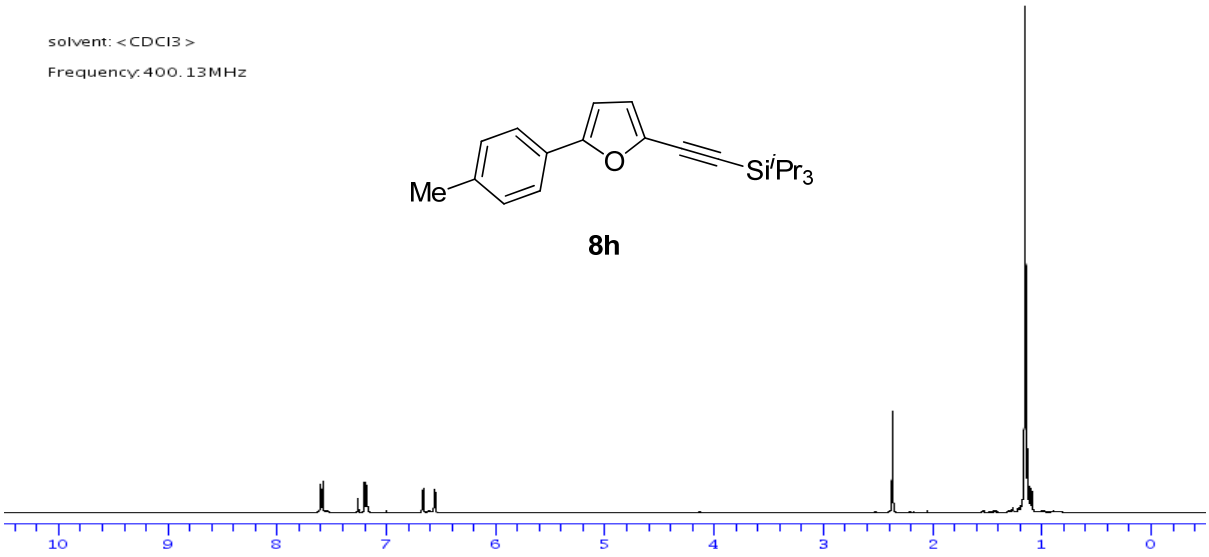
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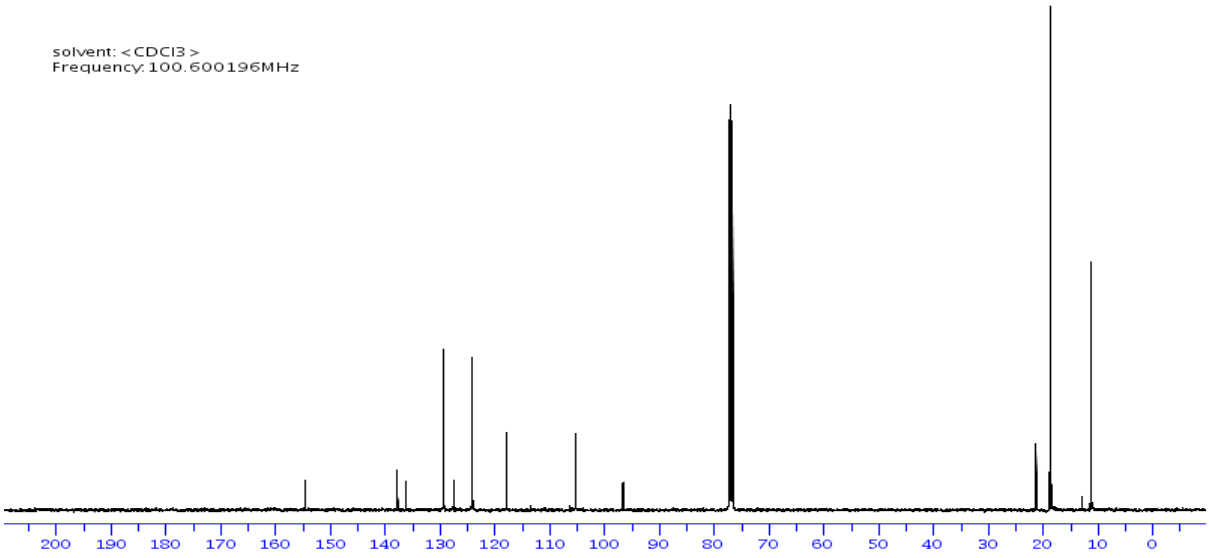
8h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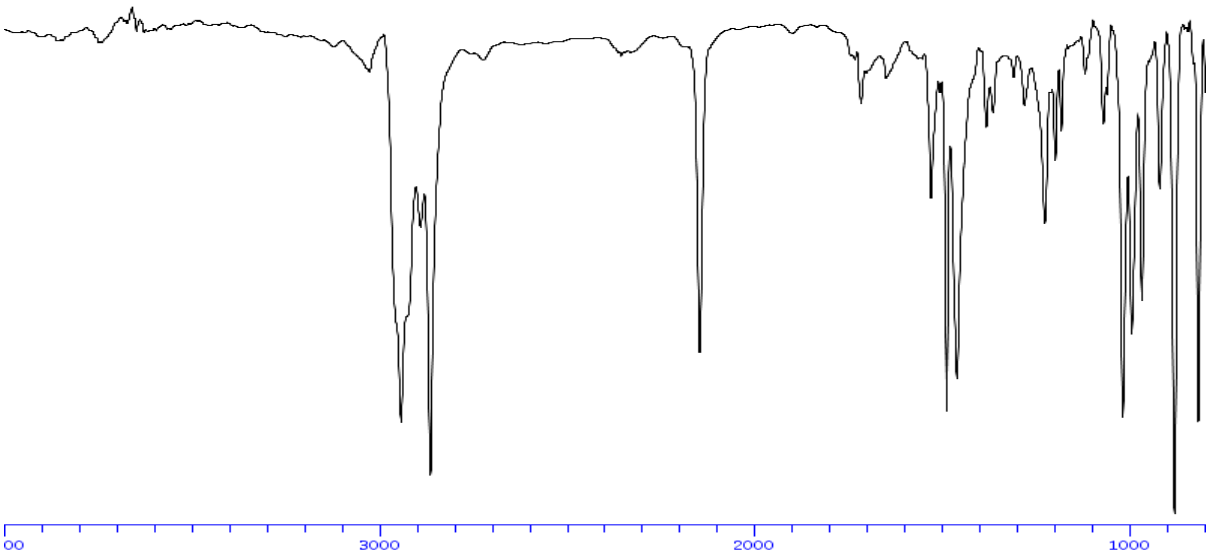
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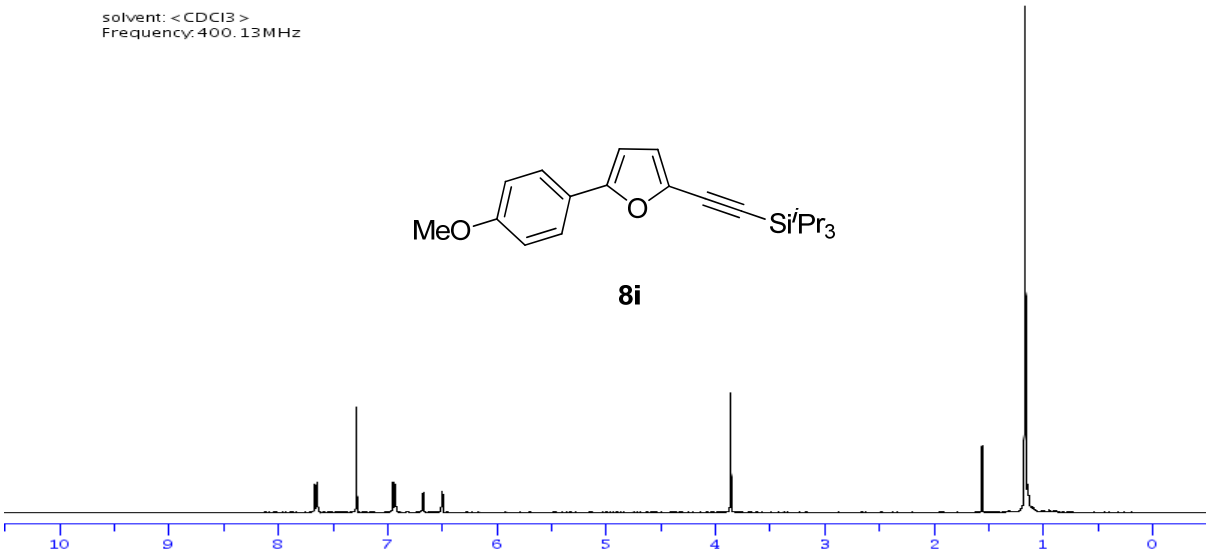
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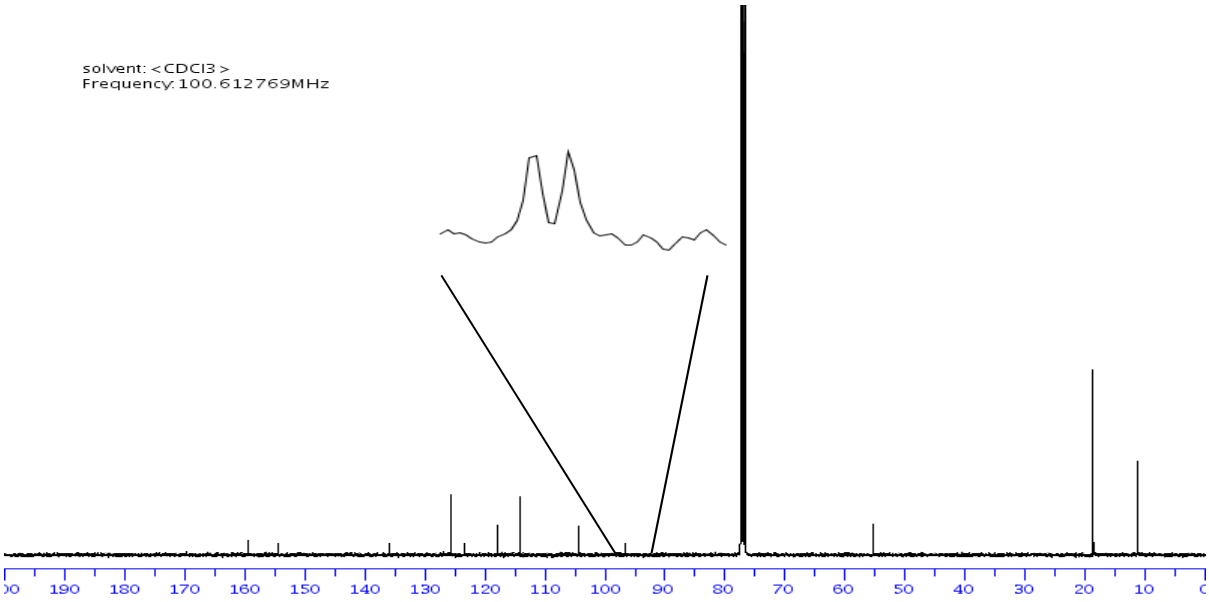
8i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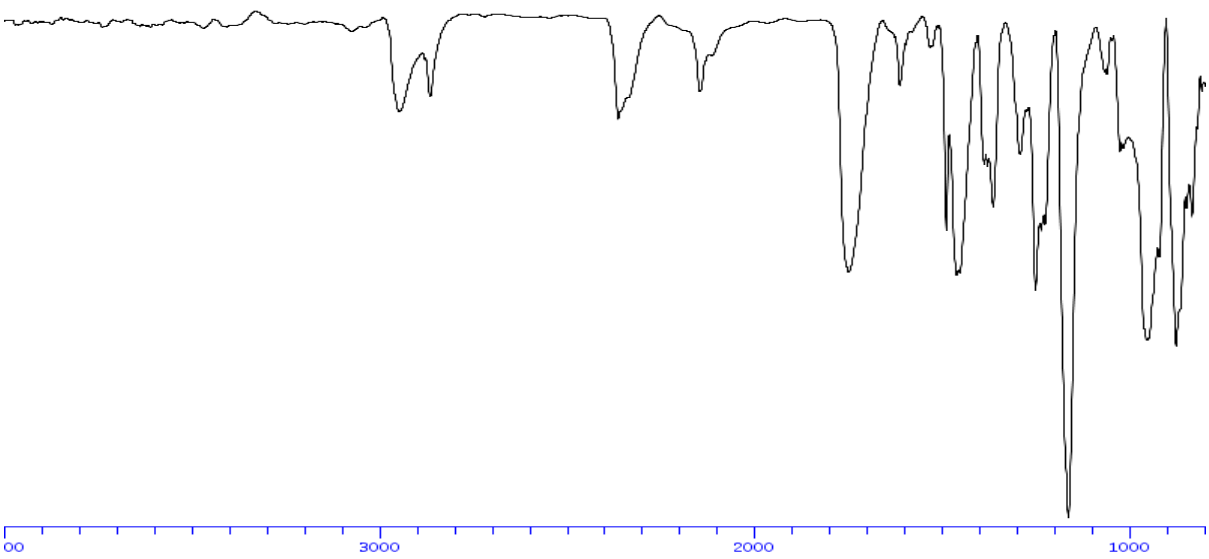
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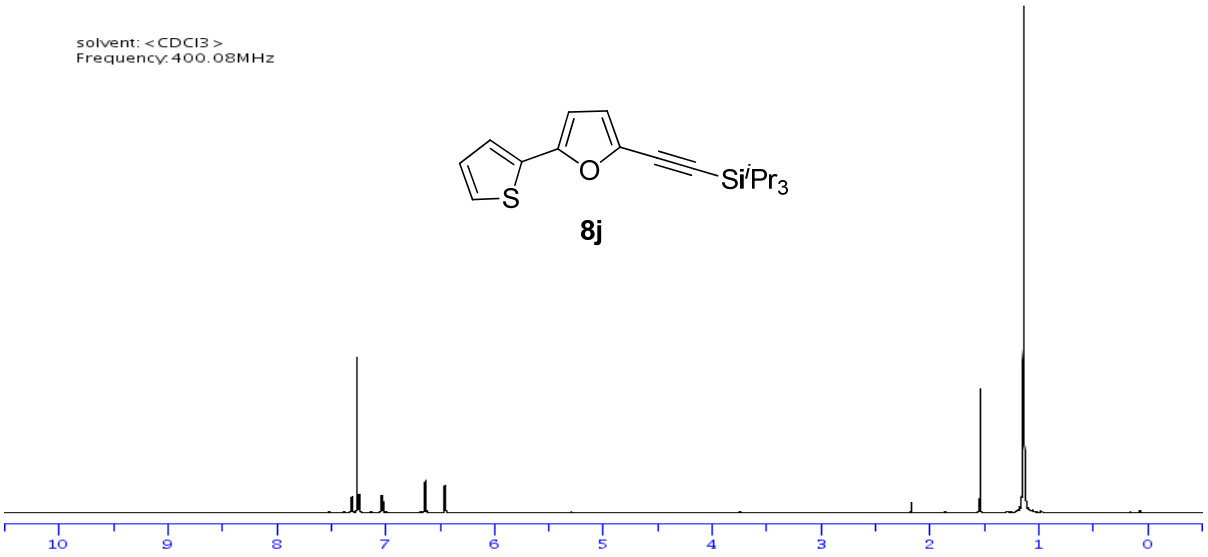
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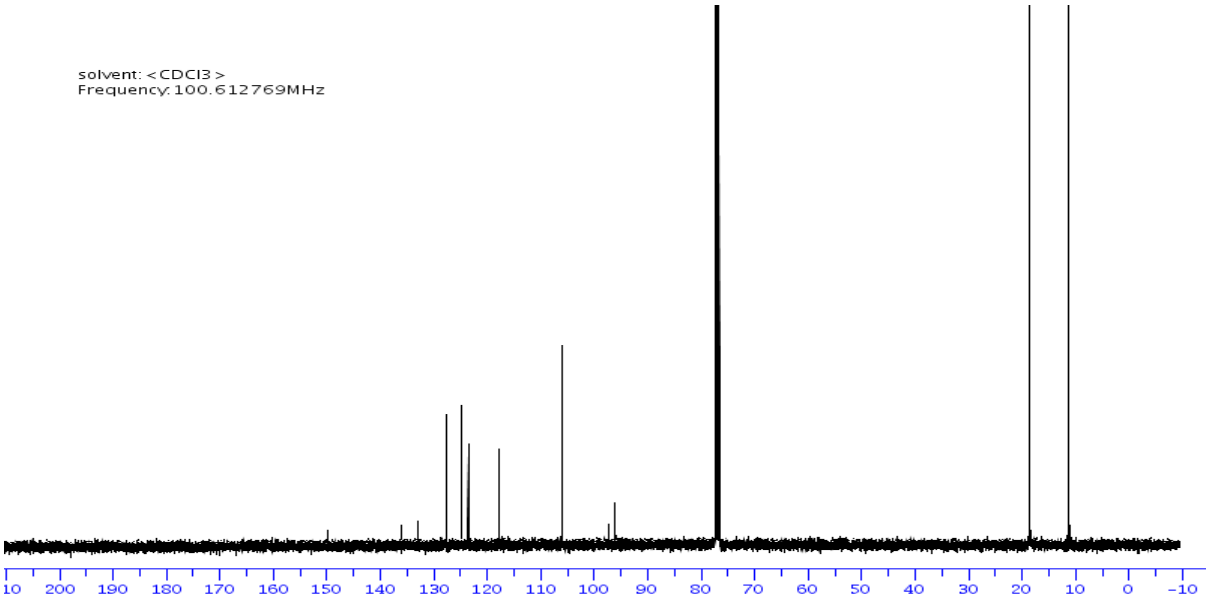
0

8j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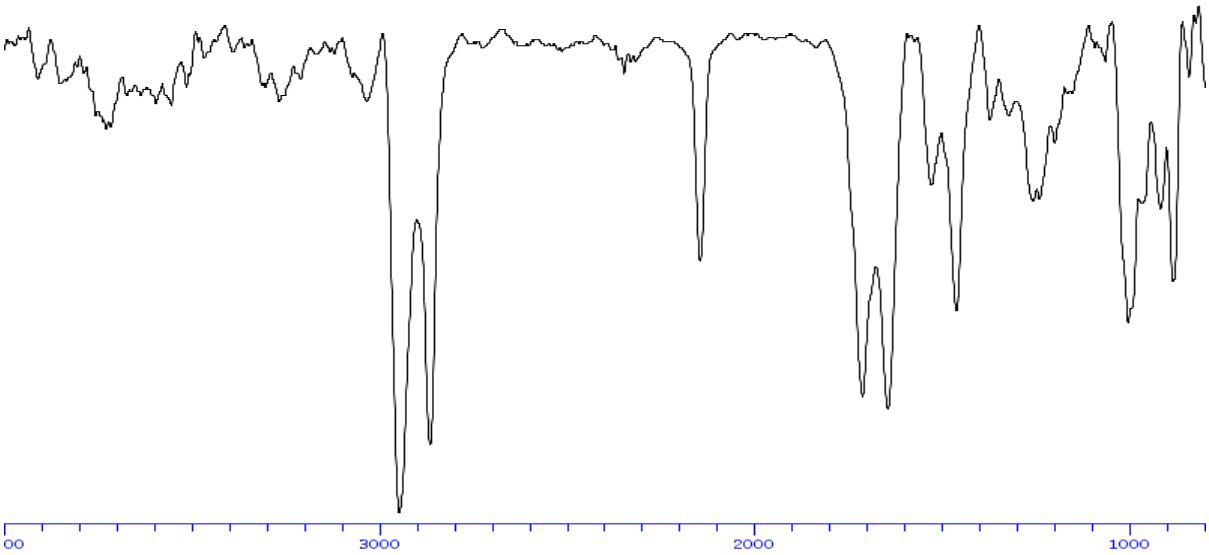
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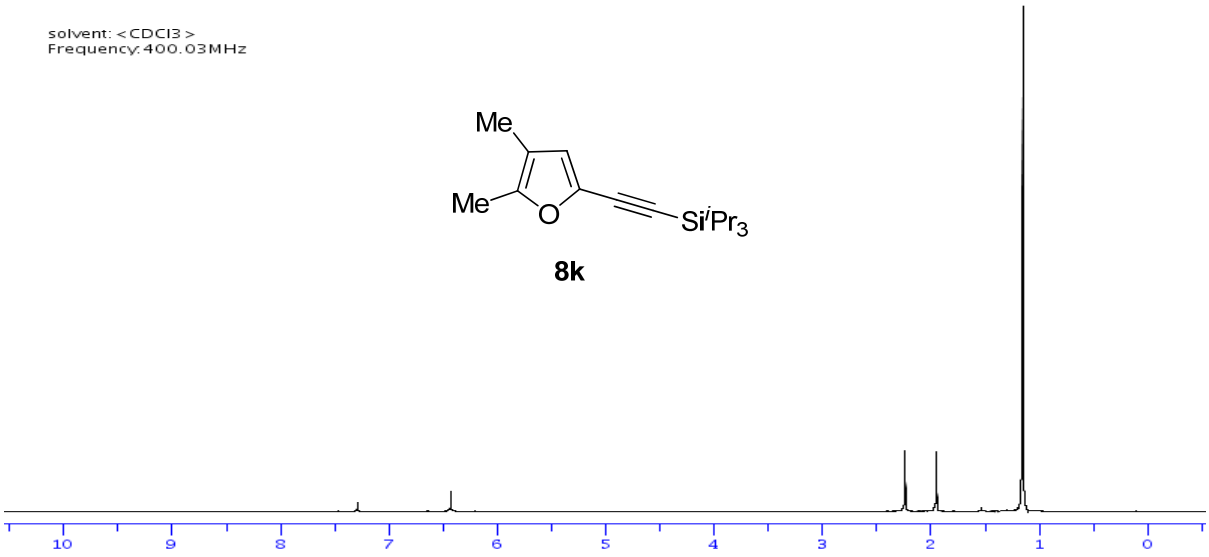
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Si^{i}Pr$_3$
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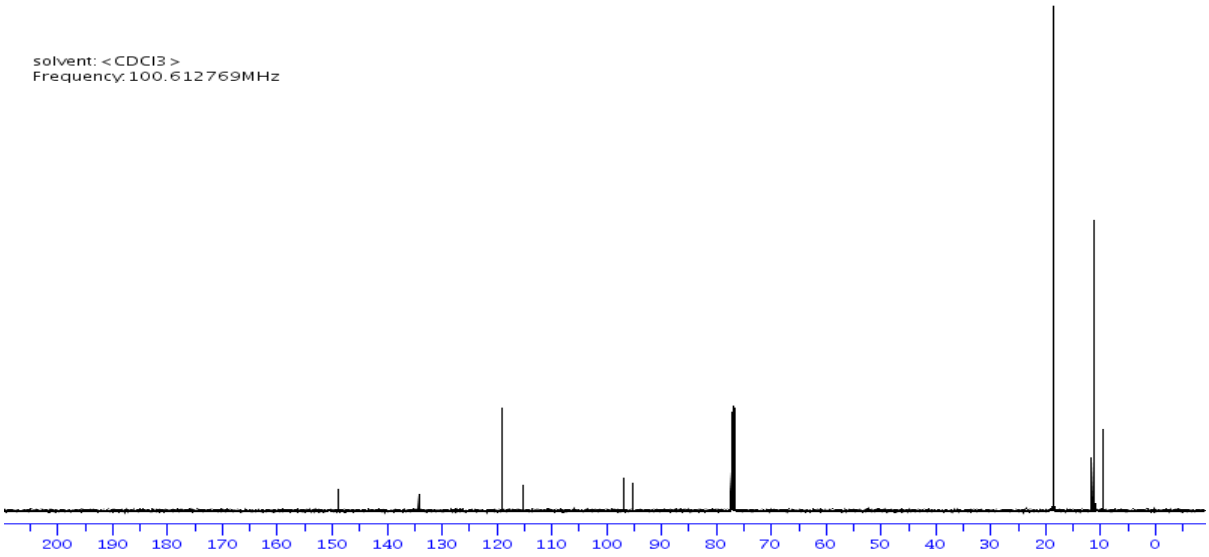
8k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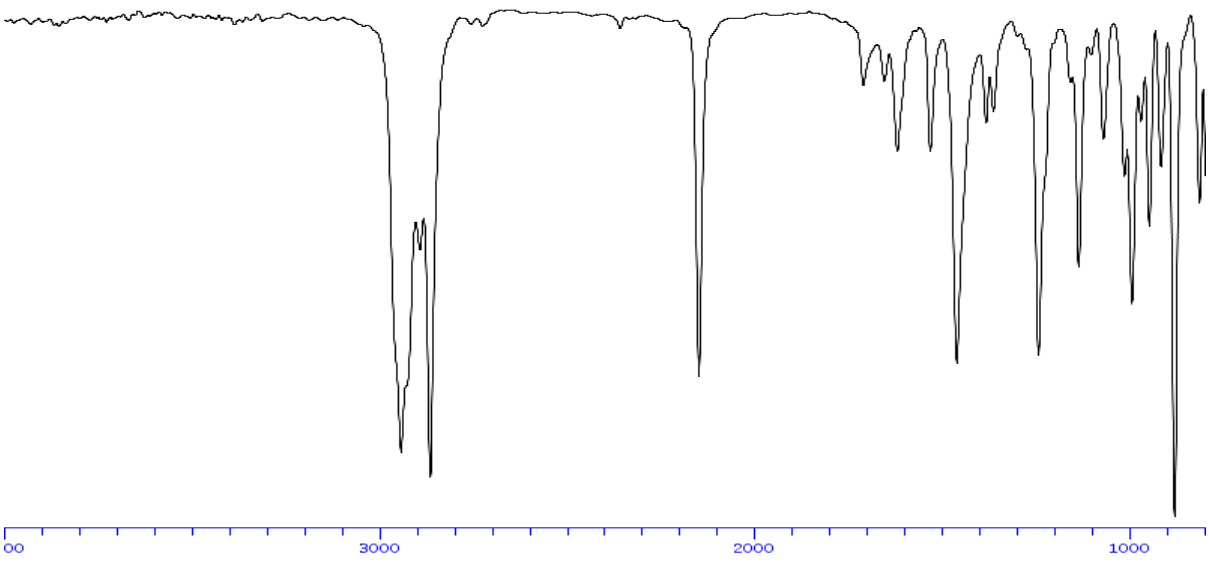
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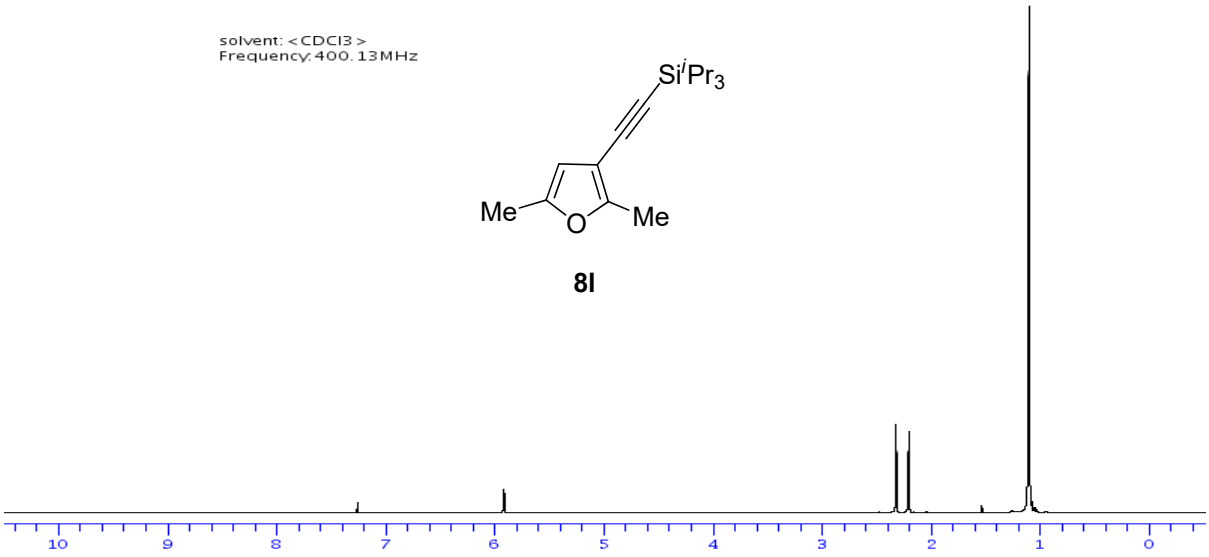
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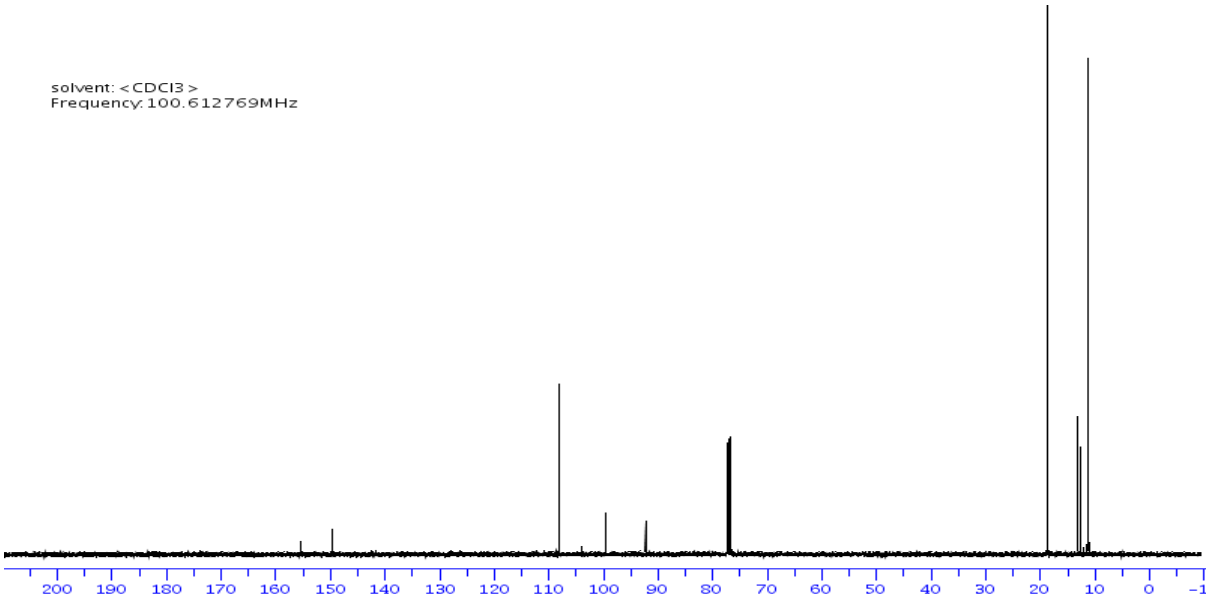
8l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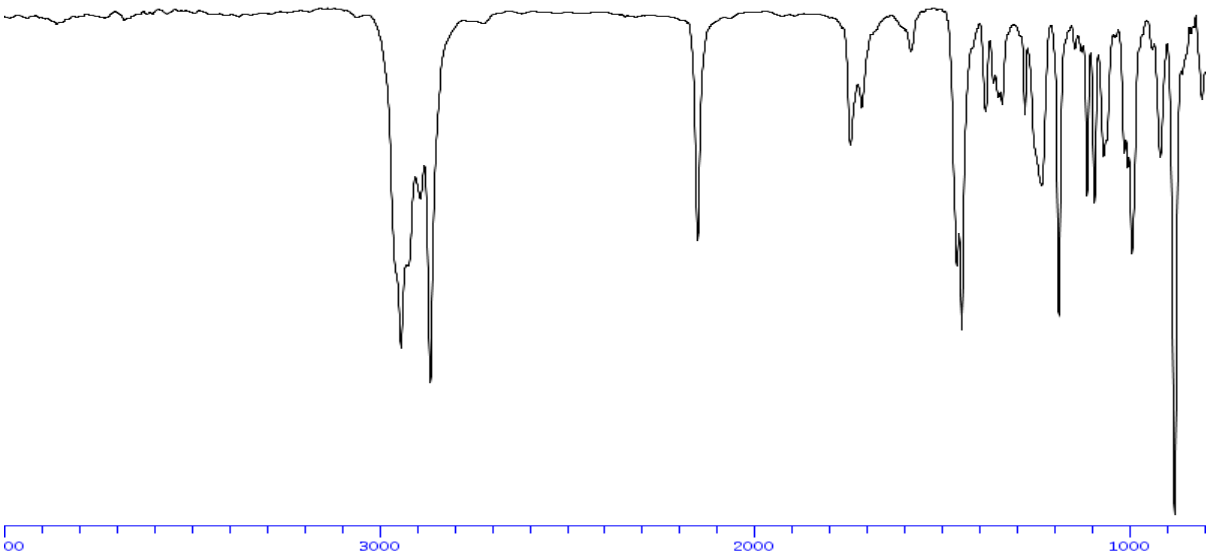
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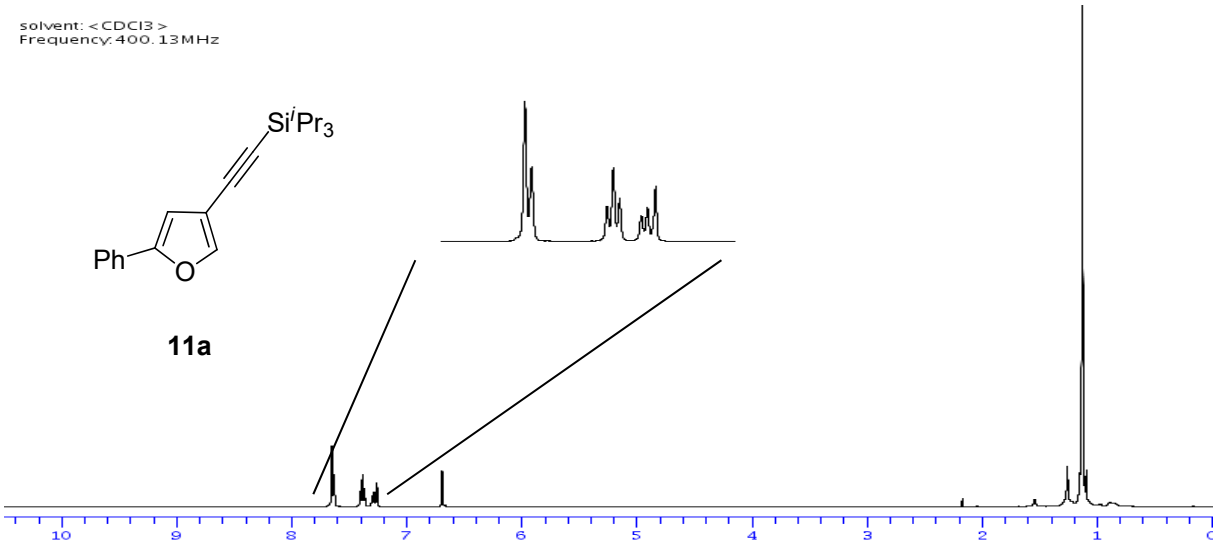
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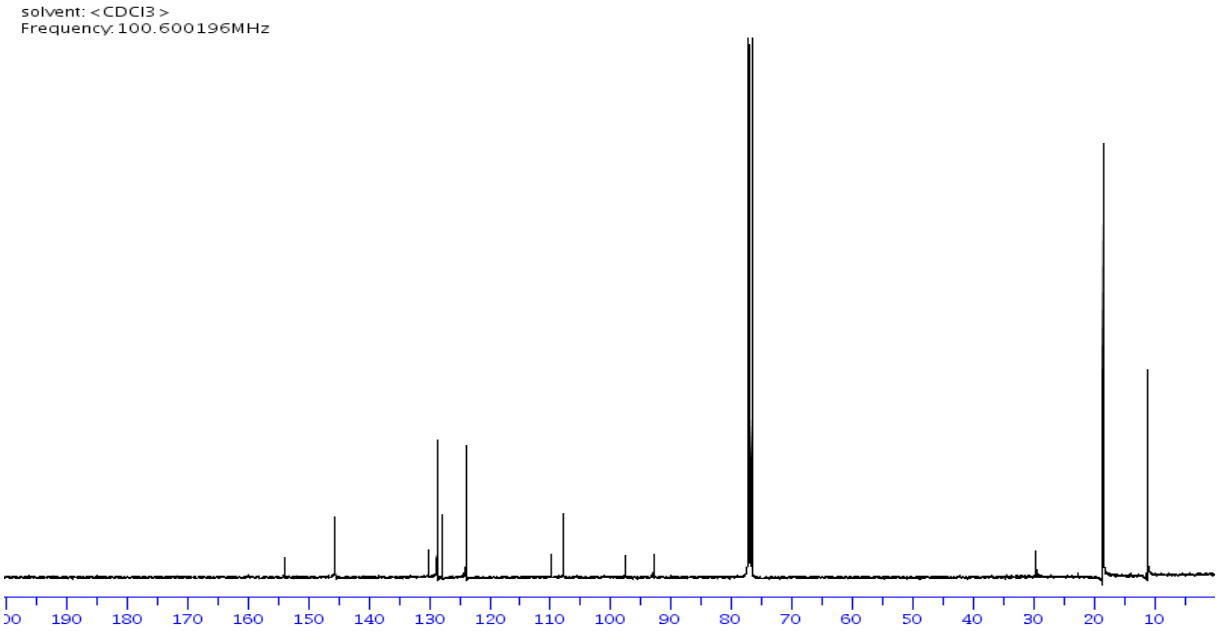
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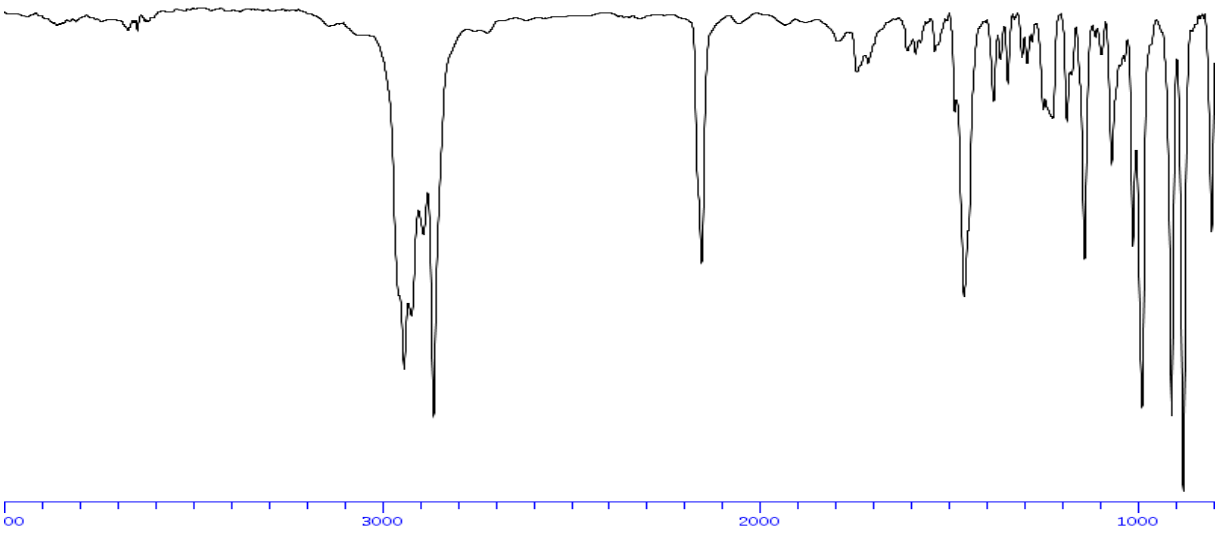
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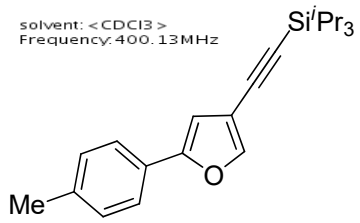
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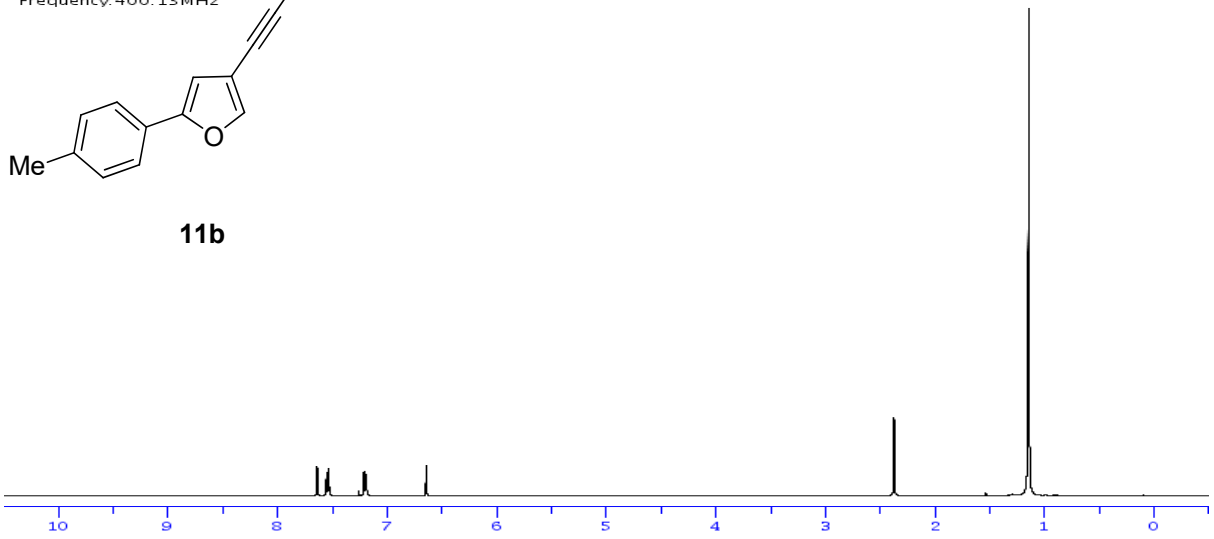
Me
O

11b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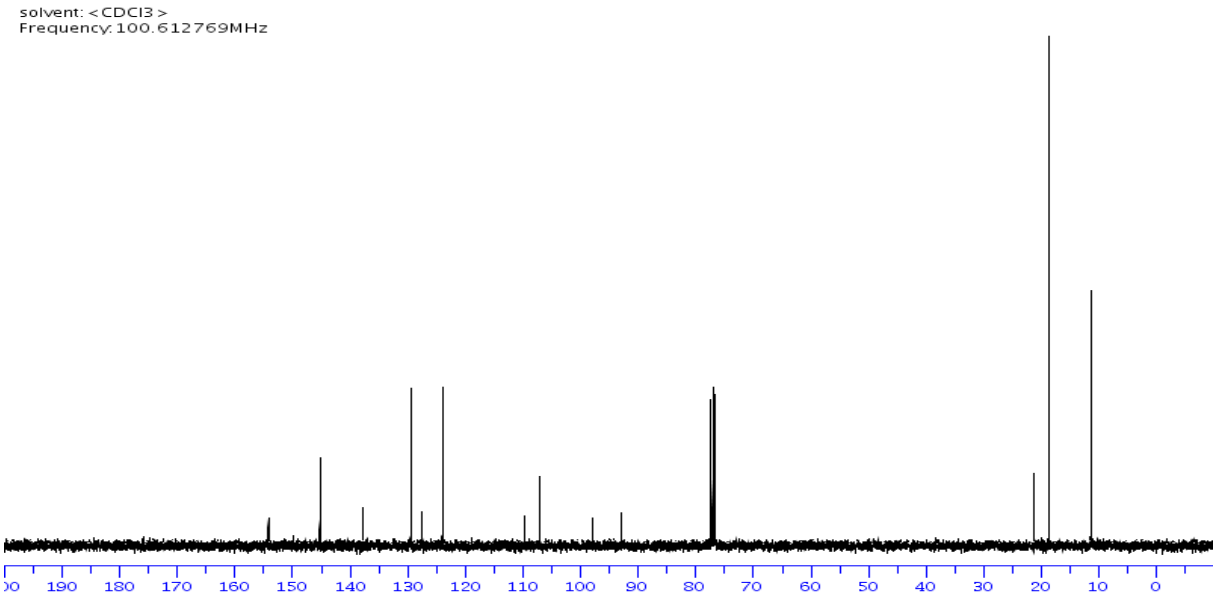
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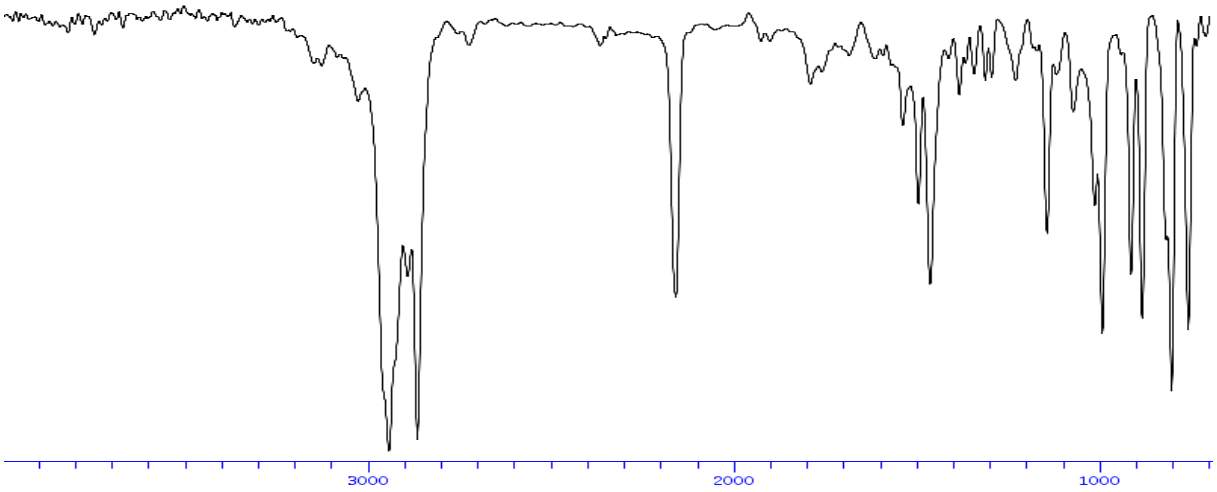
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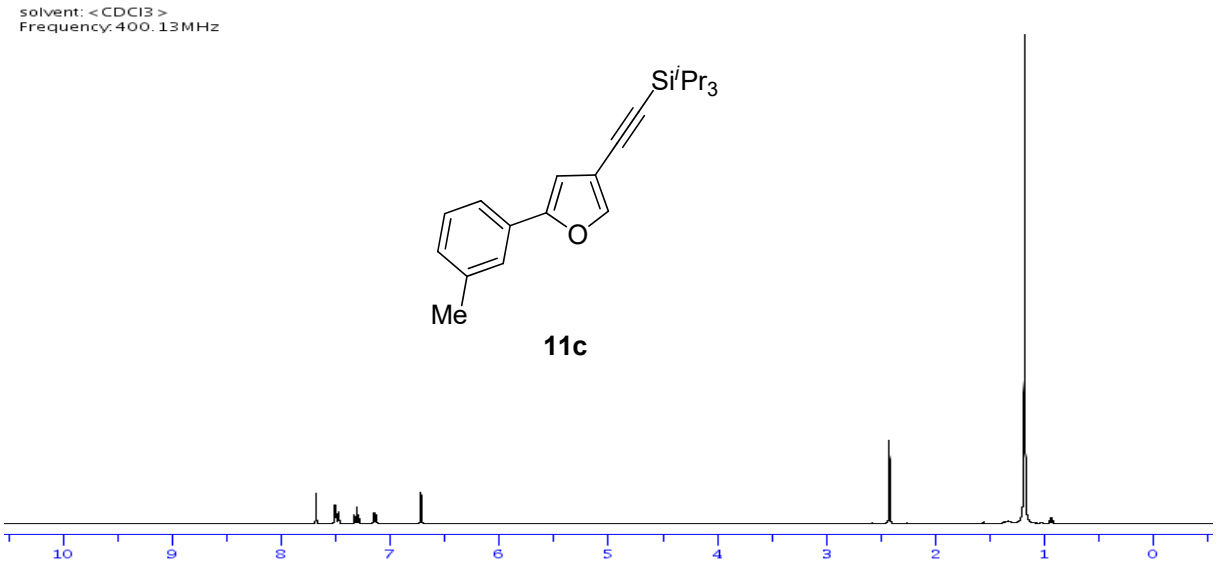
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Me
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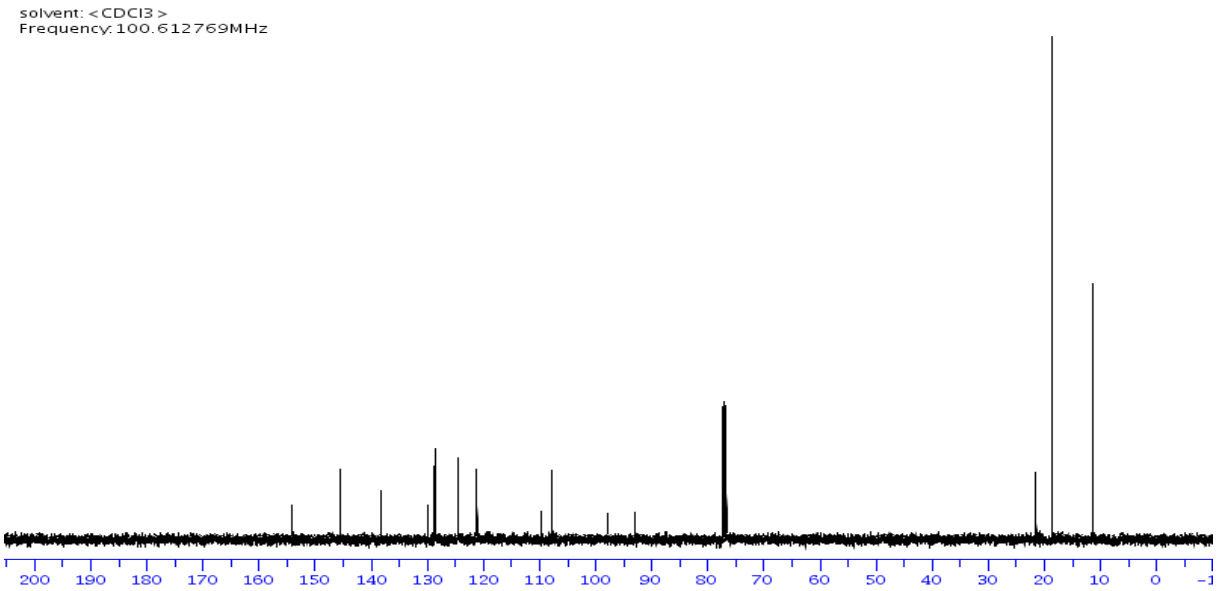
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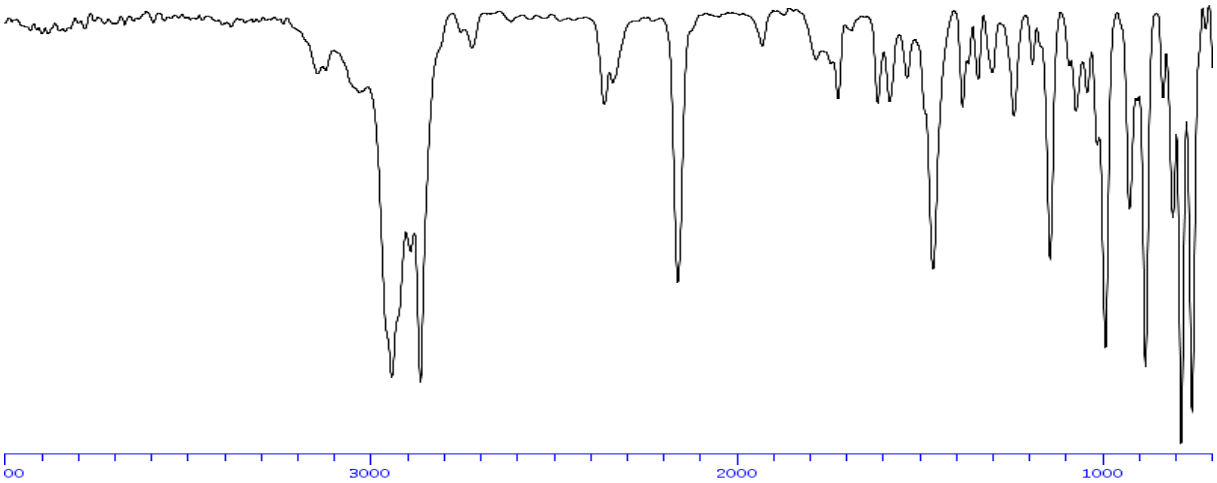
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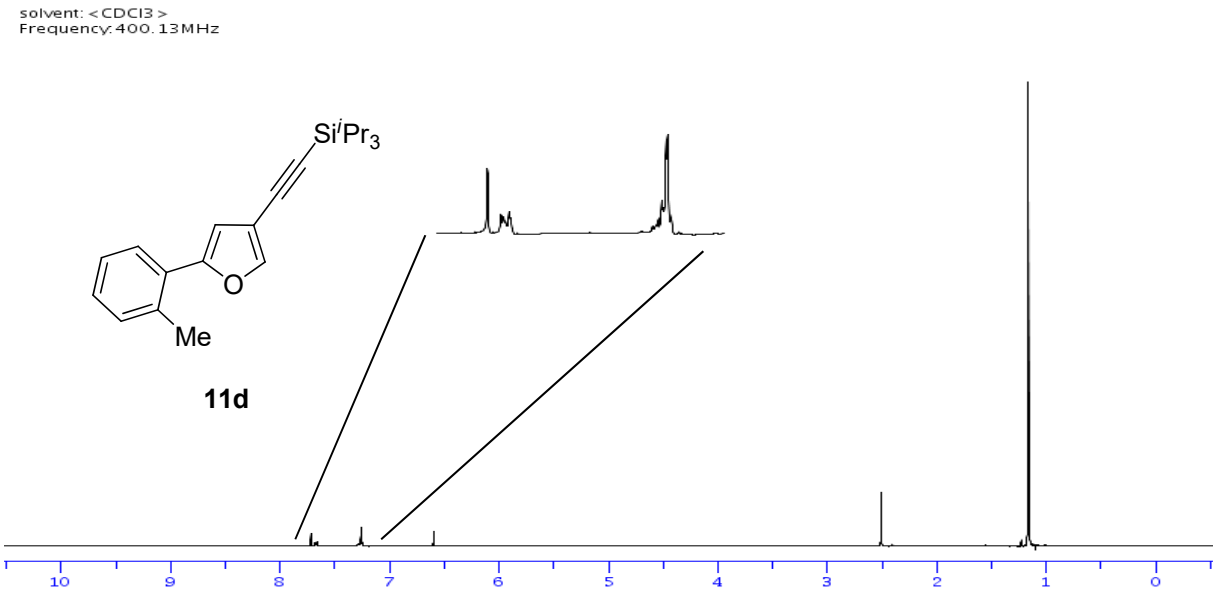
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O
Me
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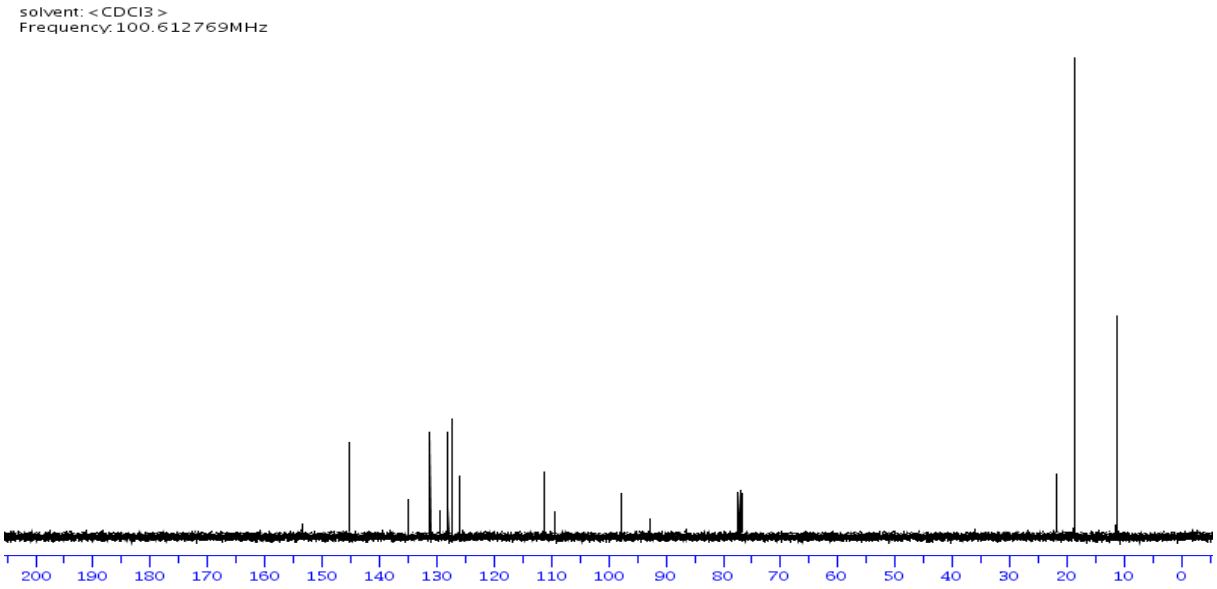
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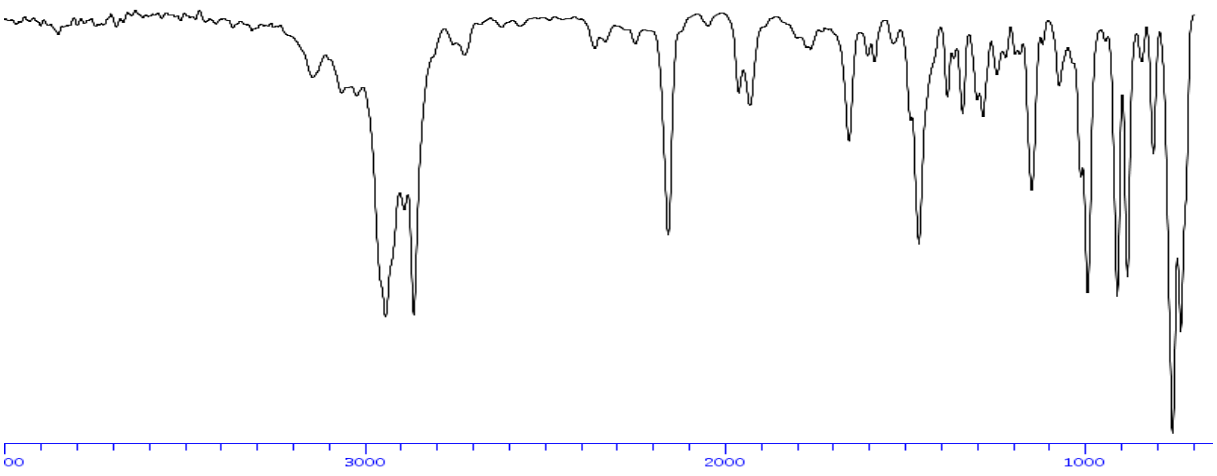
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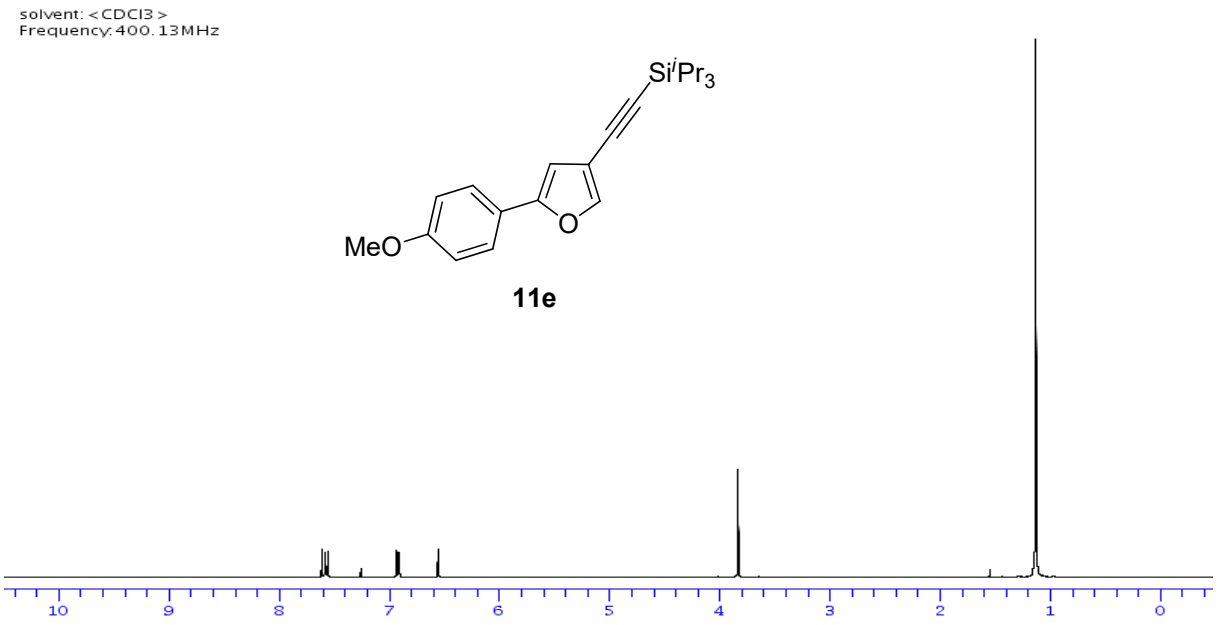
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MeO
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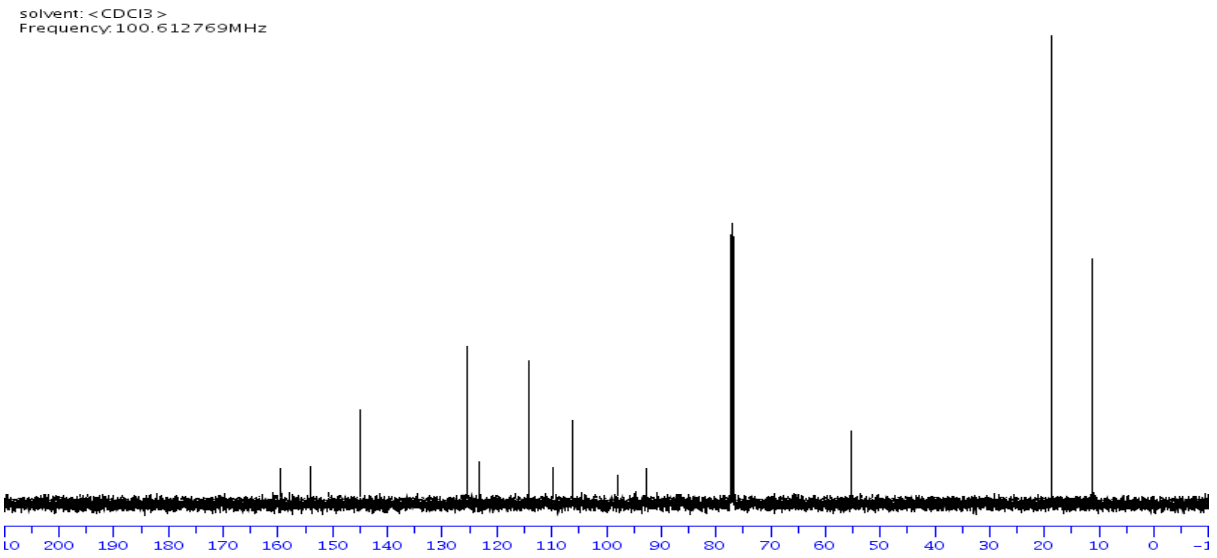
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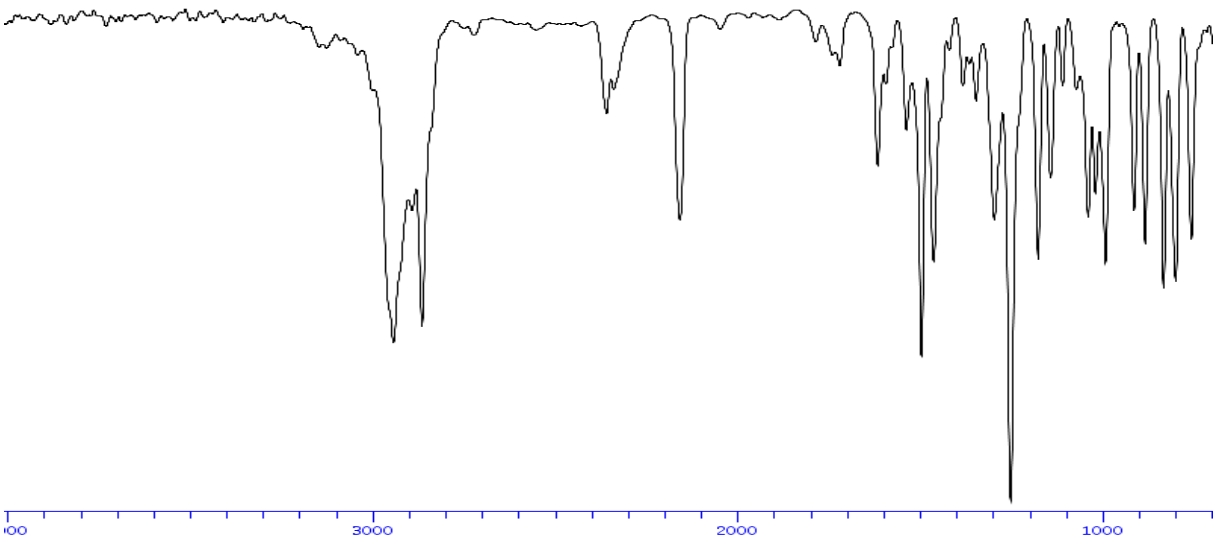
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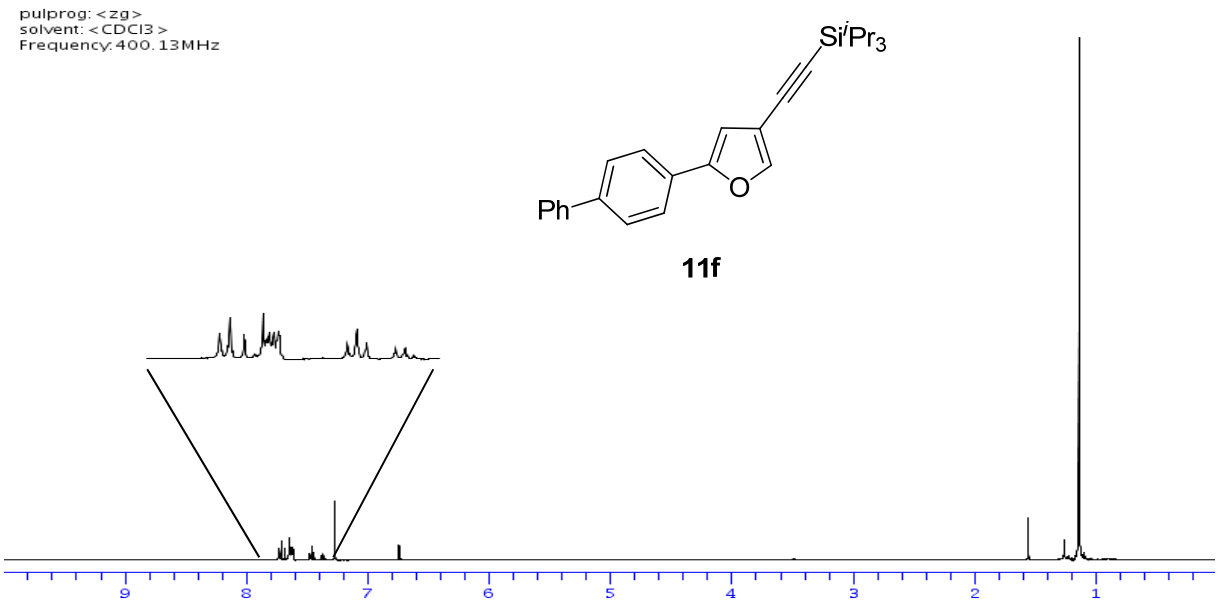
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Frequency: 400.13MHz
Si^{i}Pr$_3$
Ph
O
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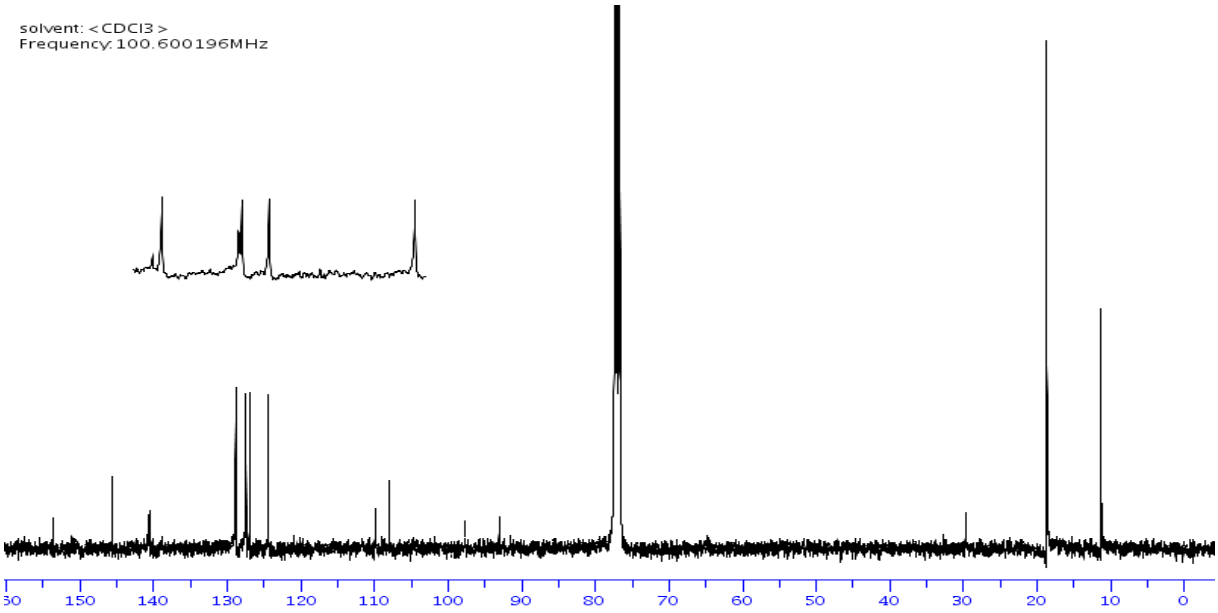
3
2
1

11f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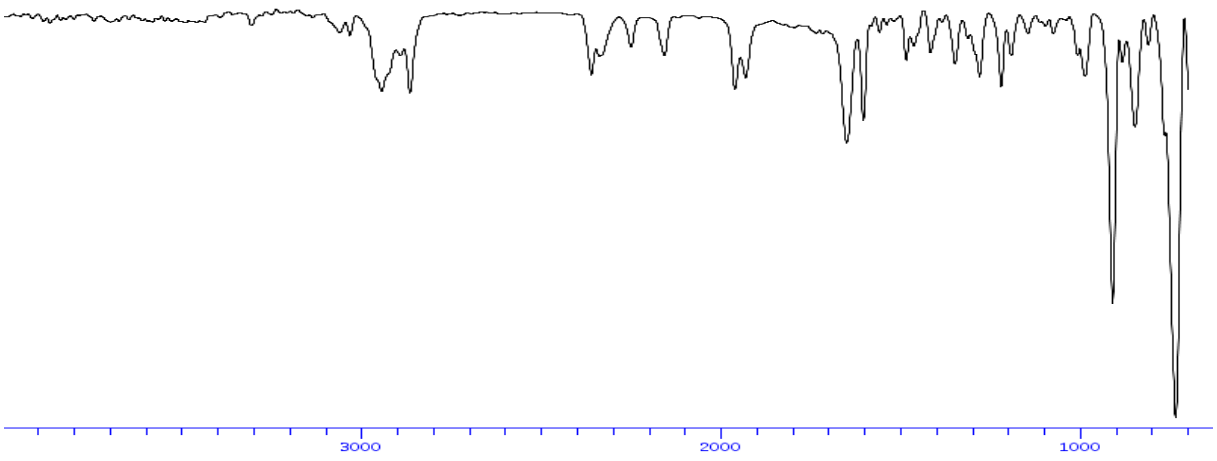
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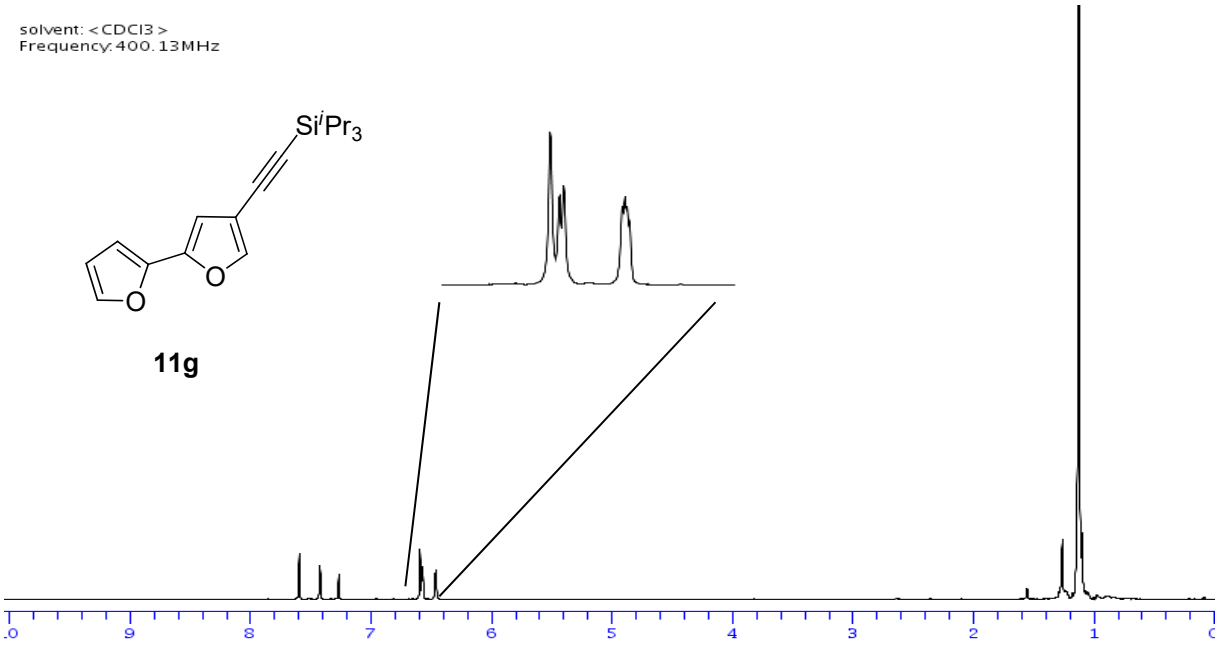
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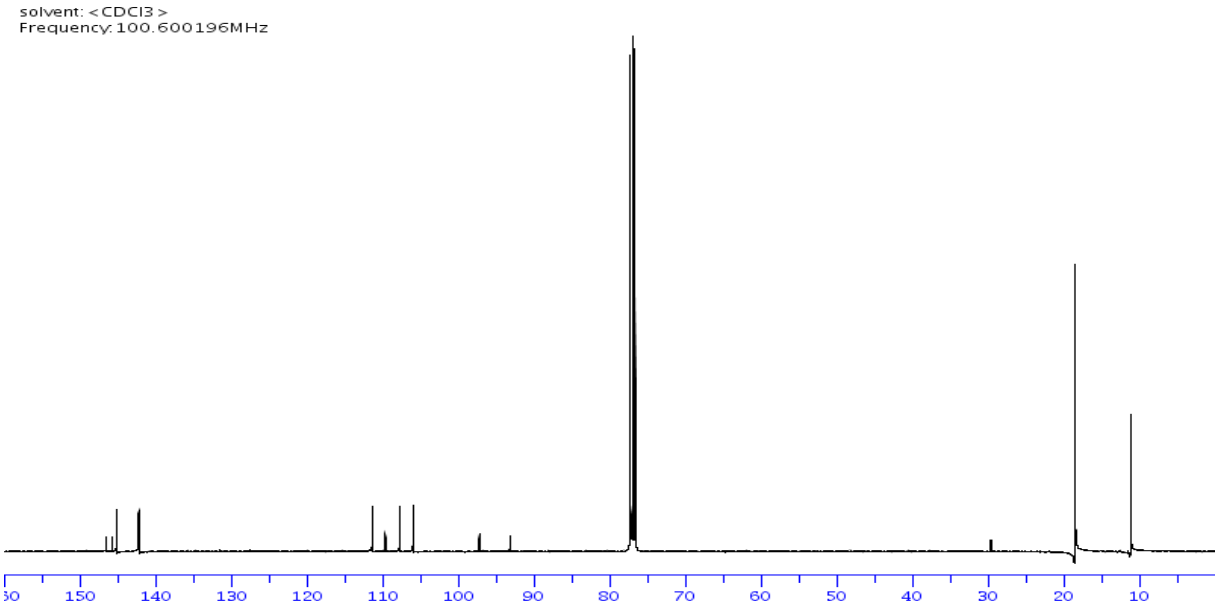
O
11g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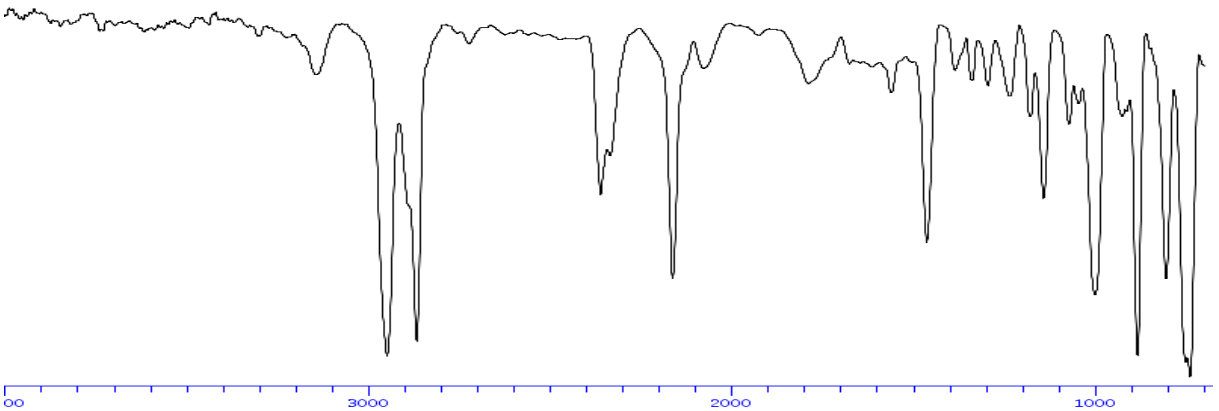

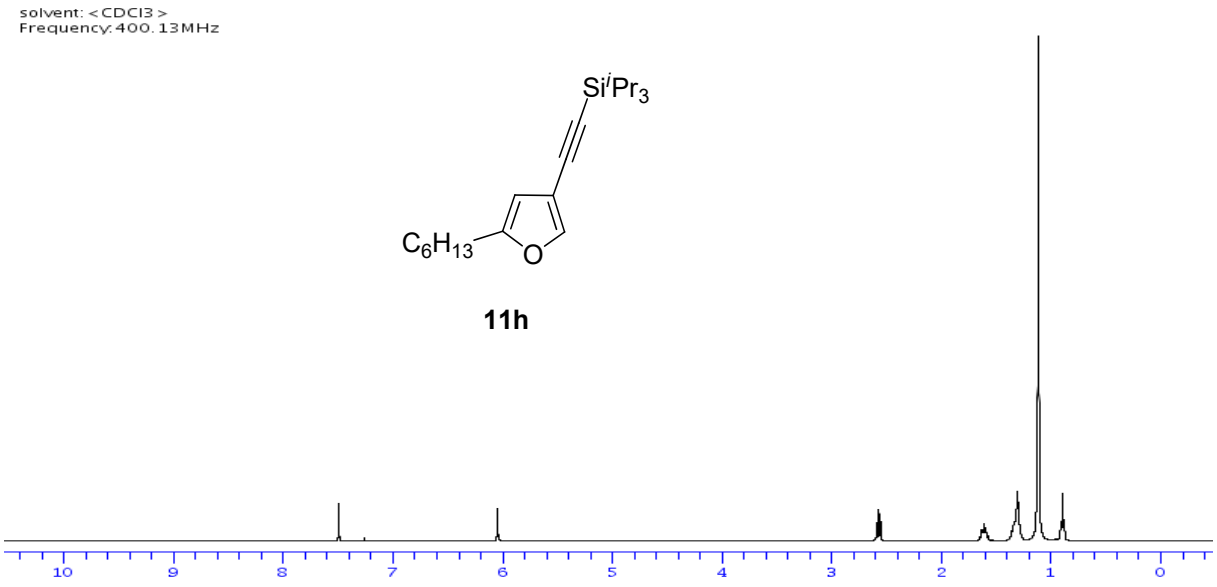
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Si^{i}Pr$_3$
C$_6$H$_{13}$
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8
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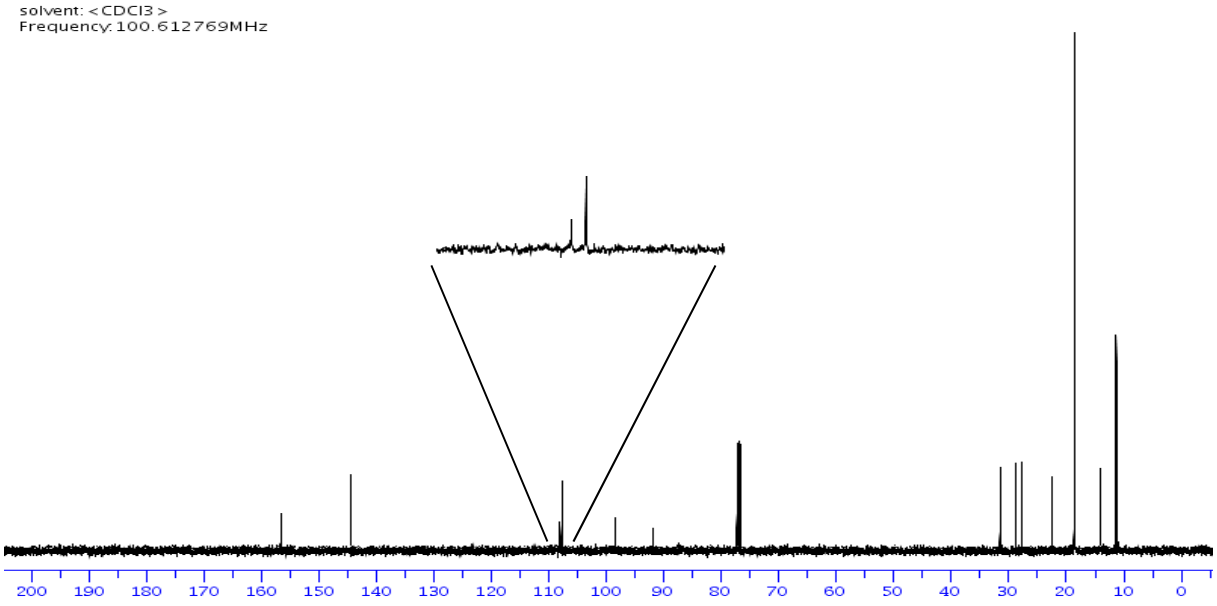
2
1
0

11h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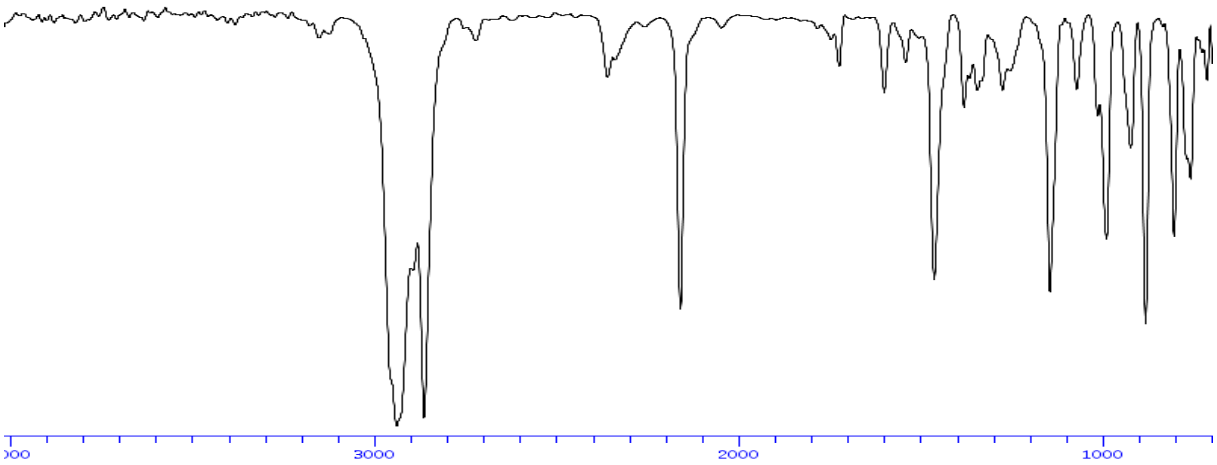
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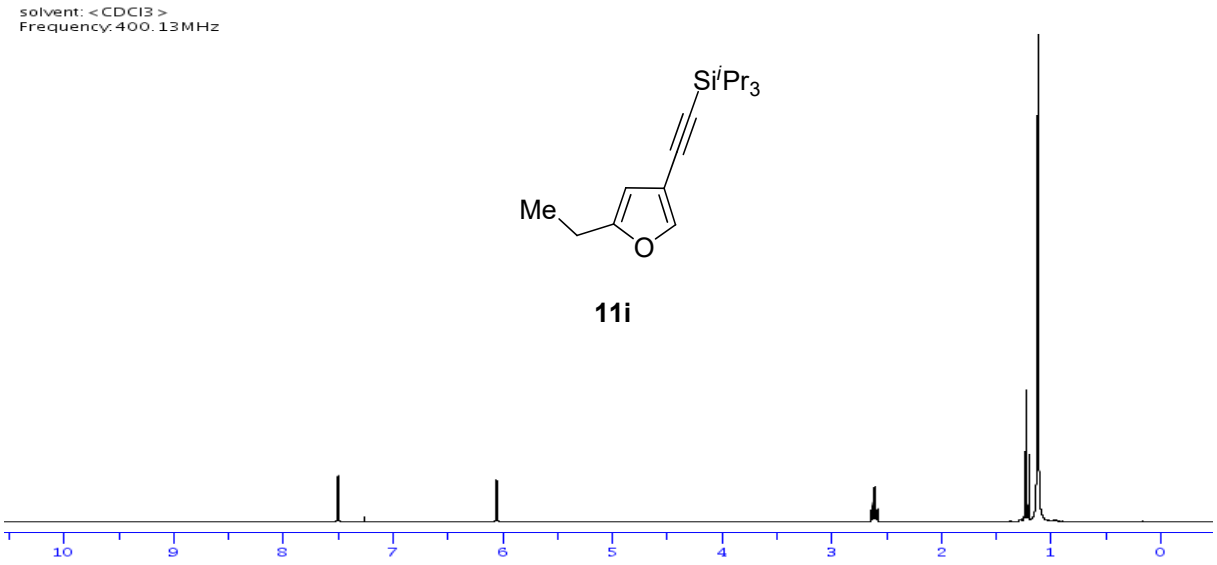
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Me
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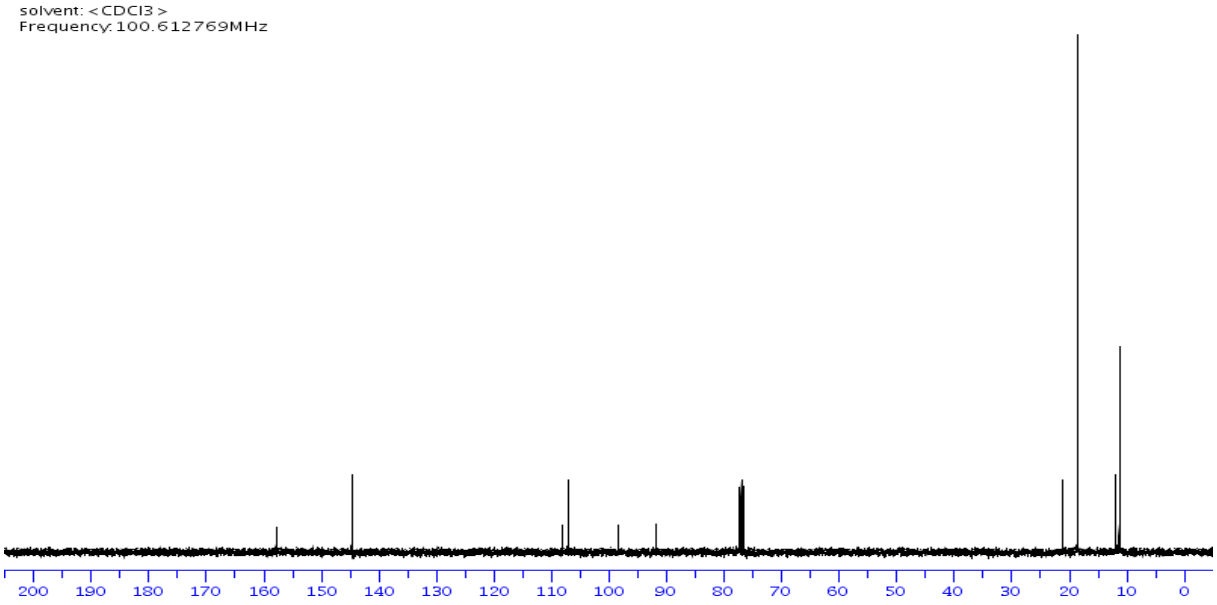
11i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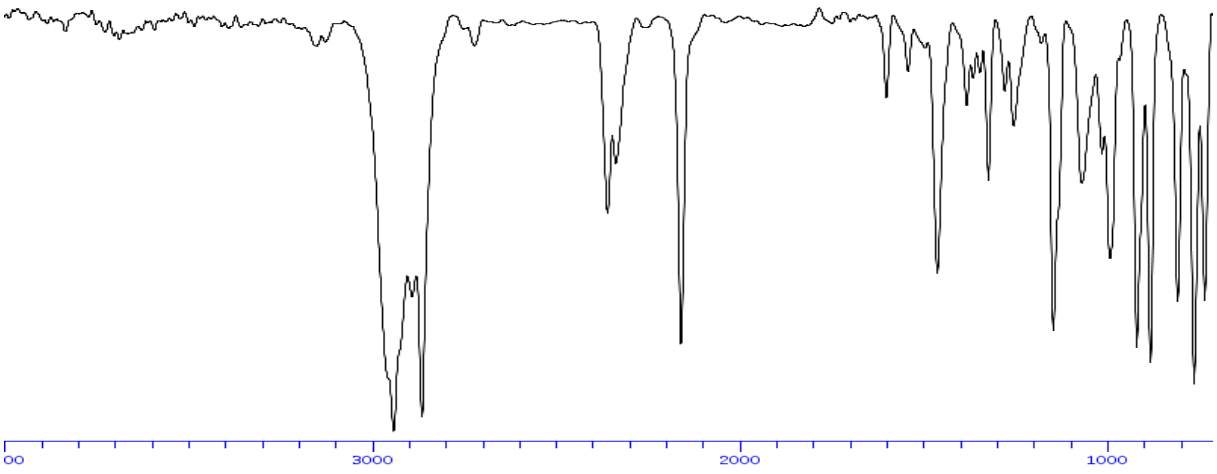
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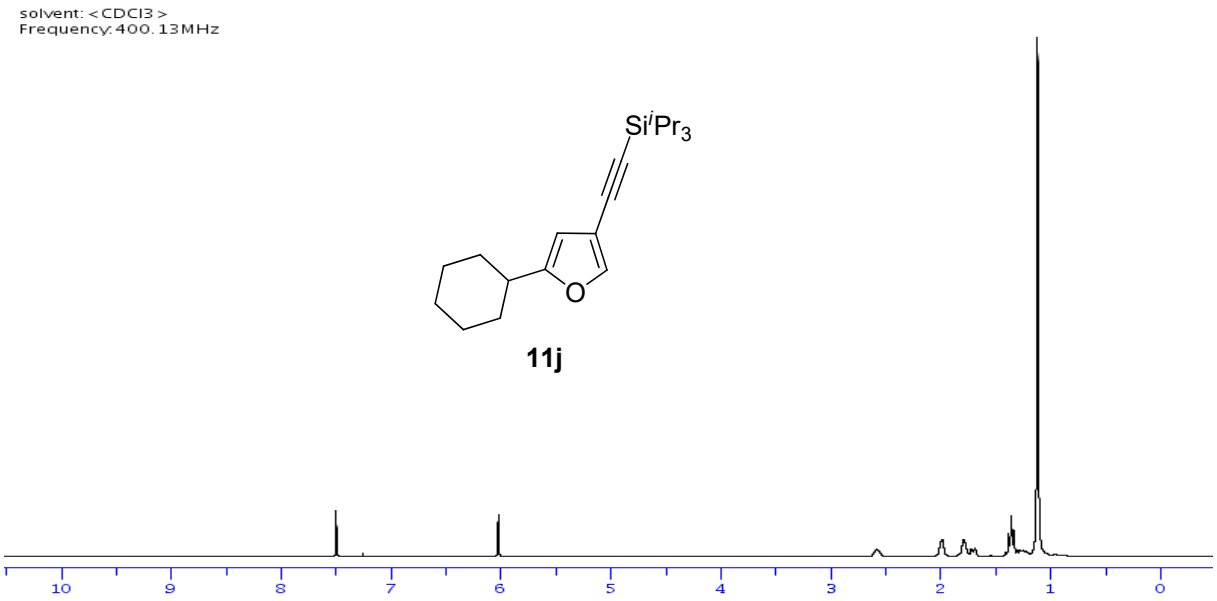
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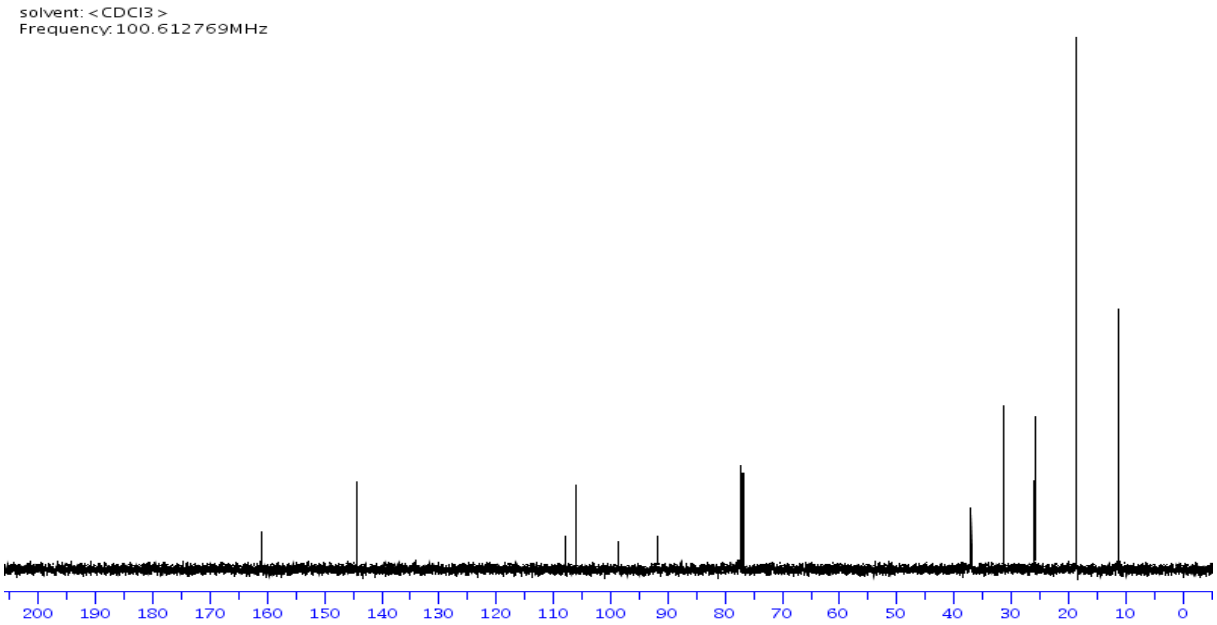
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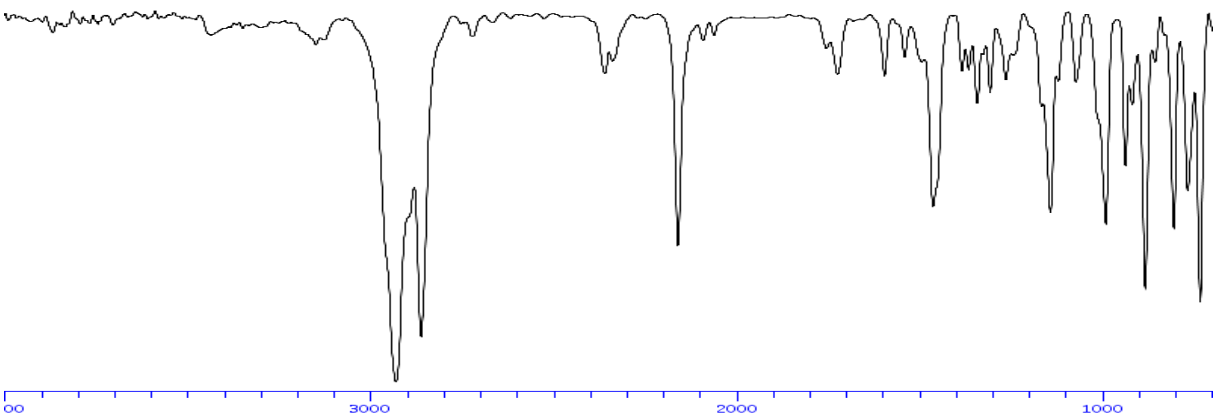
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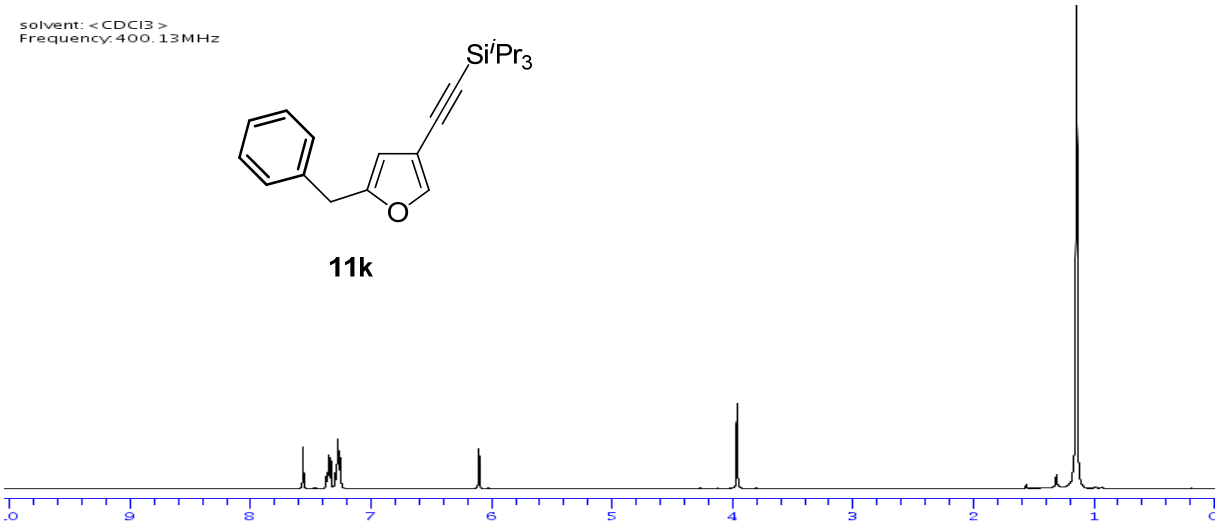
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O
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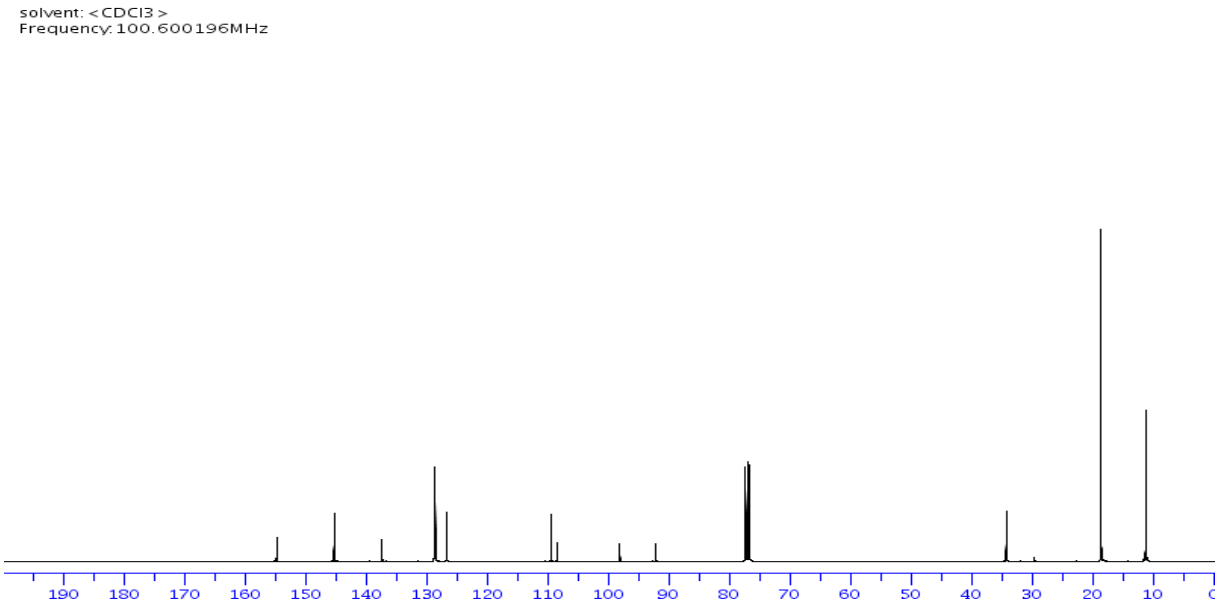
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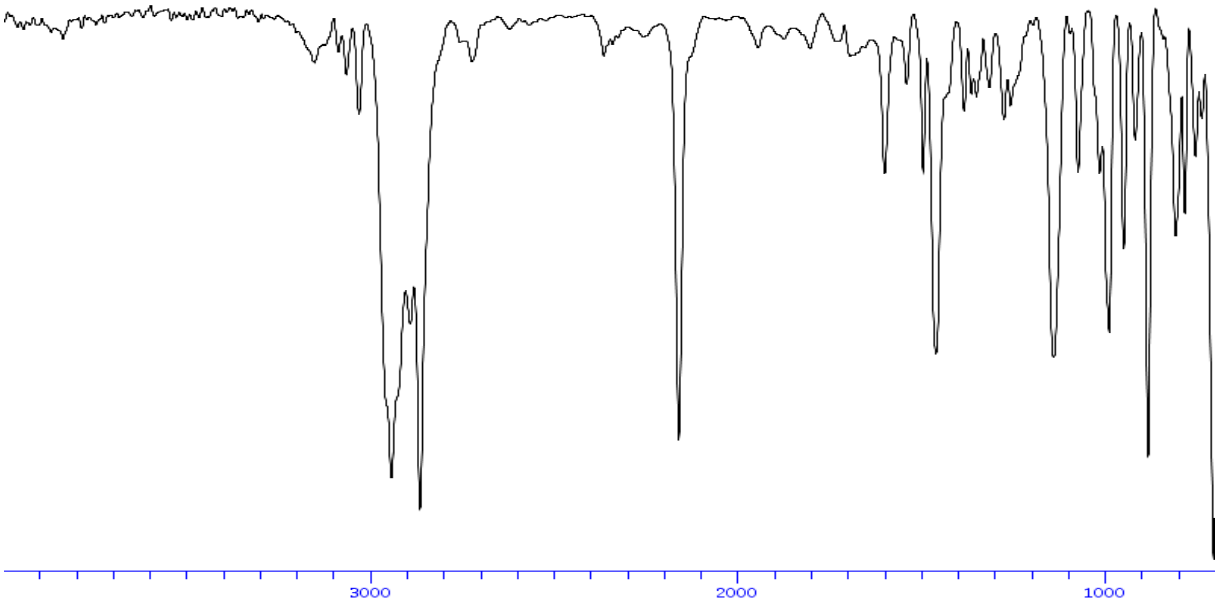
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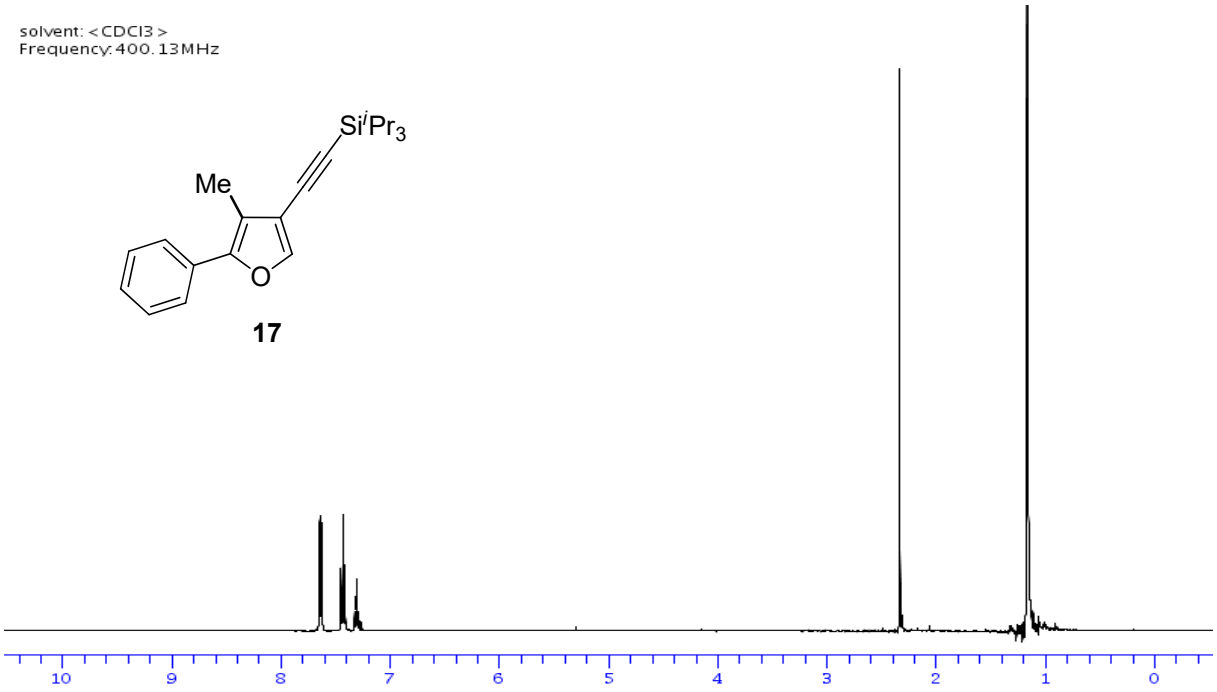
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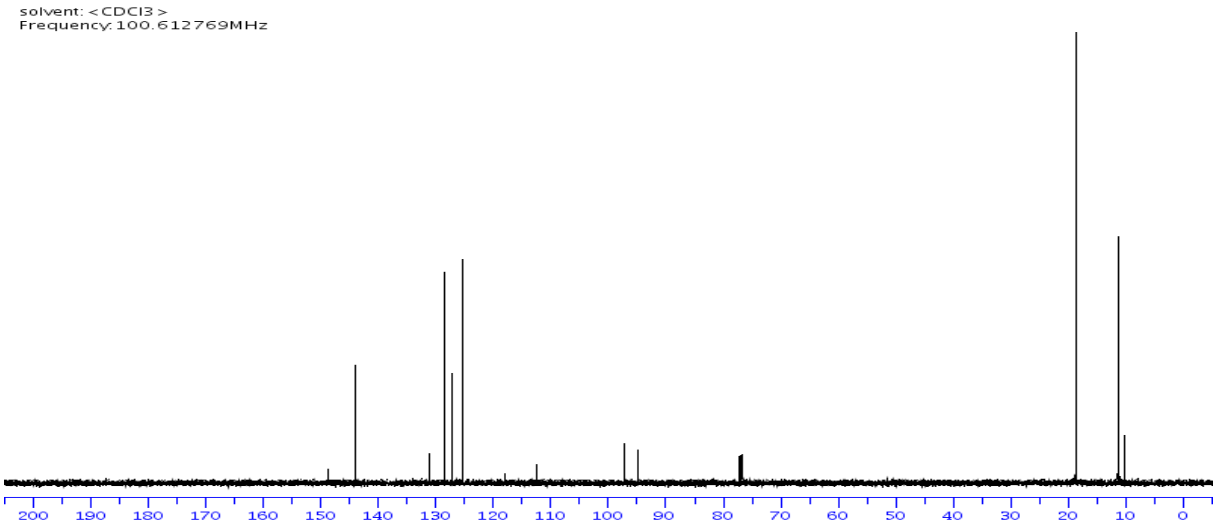
0

17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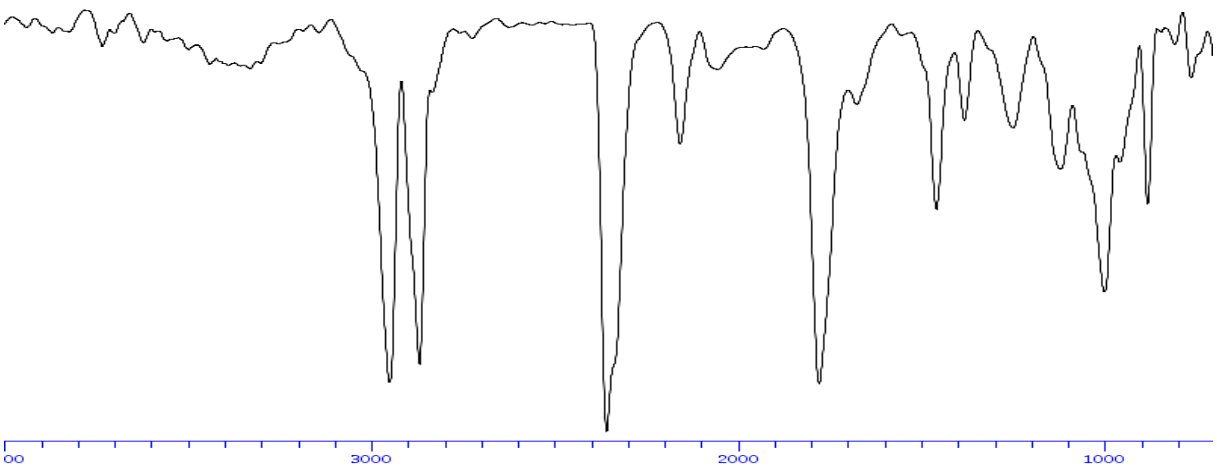
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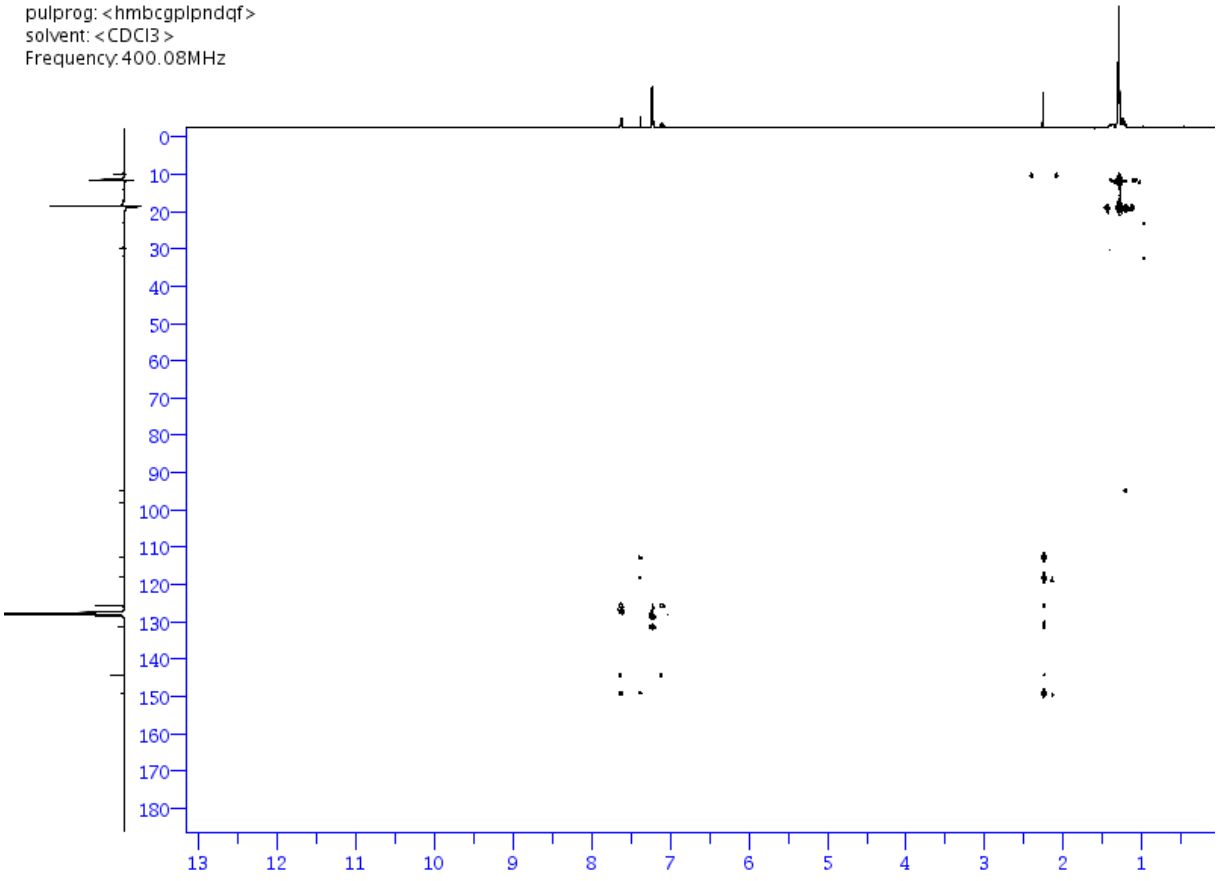
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8
7
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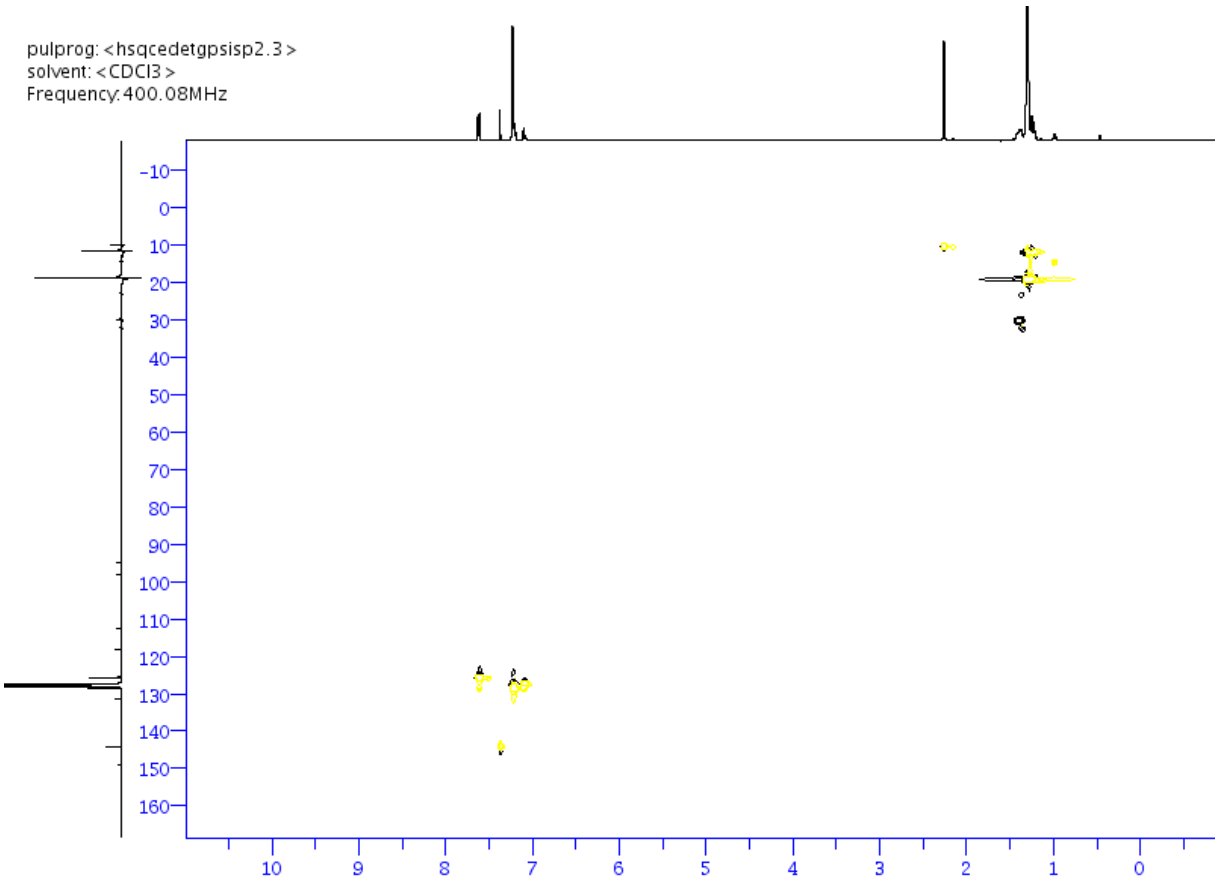
4
3
2
1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60
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90
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9
8
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5
4
3
2
1
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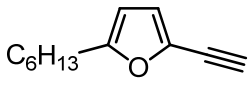
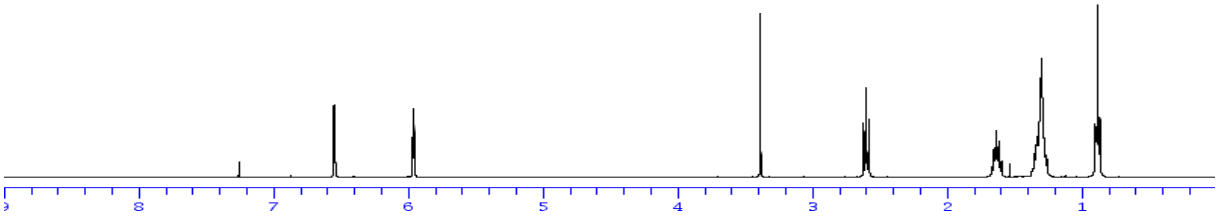


47



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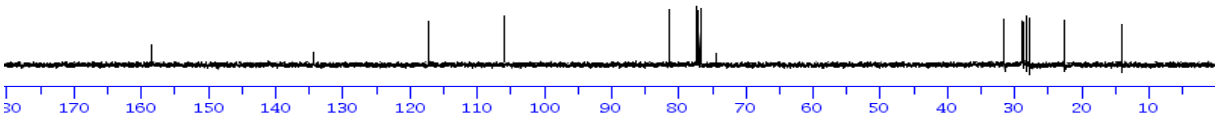

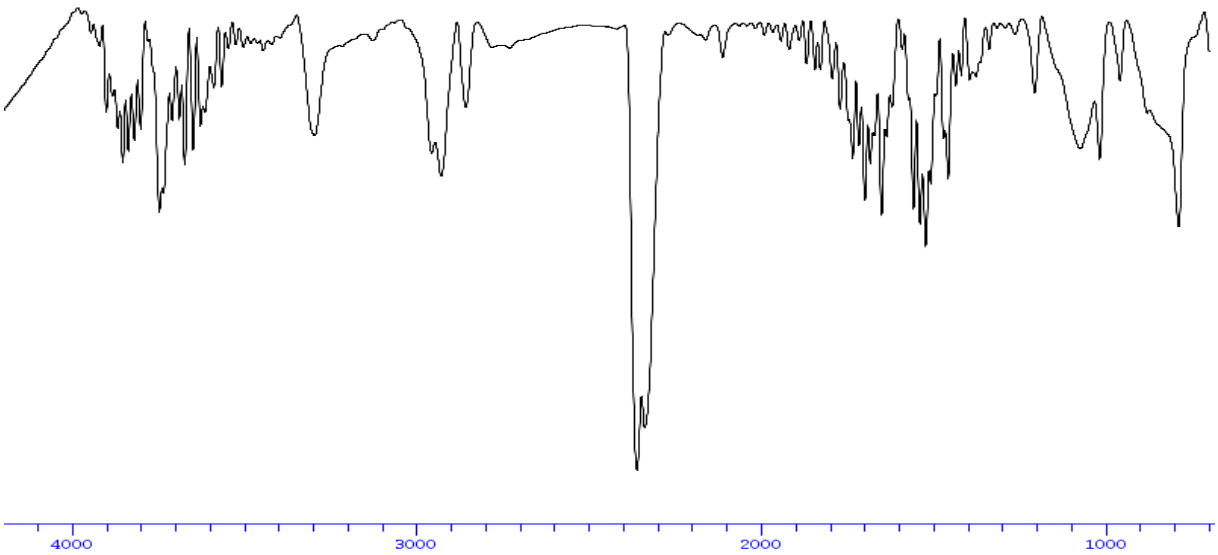

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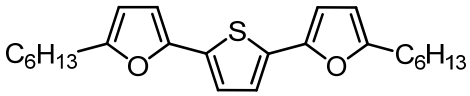
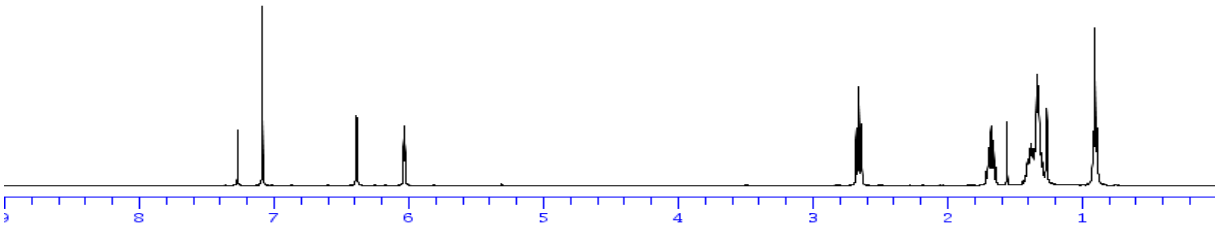


18



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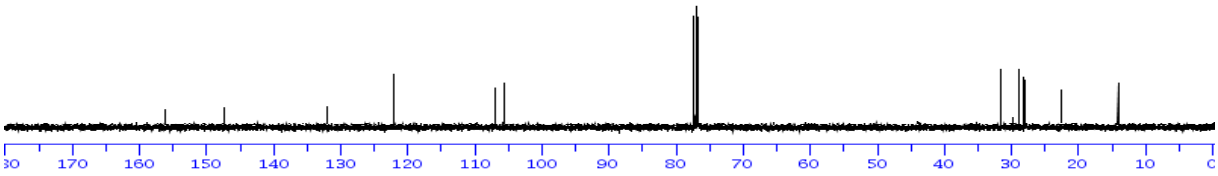

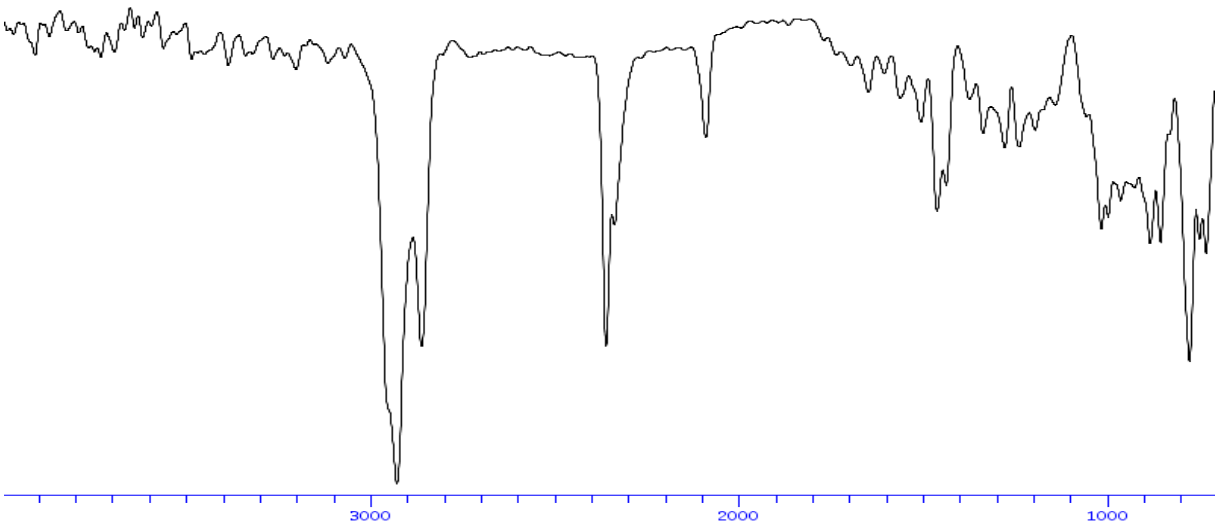

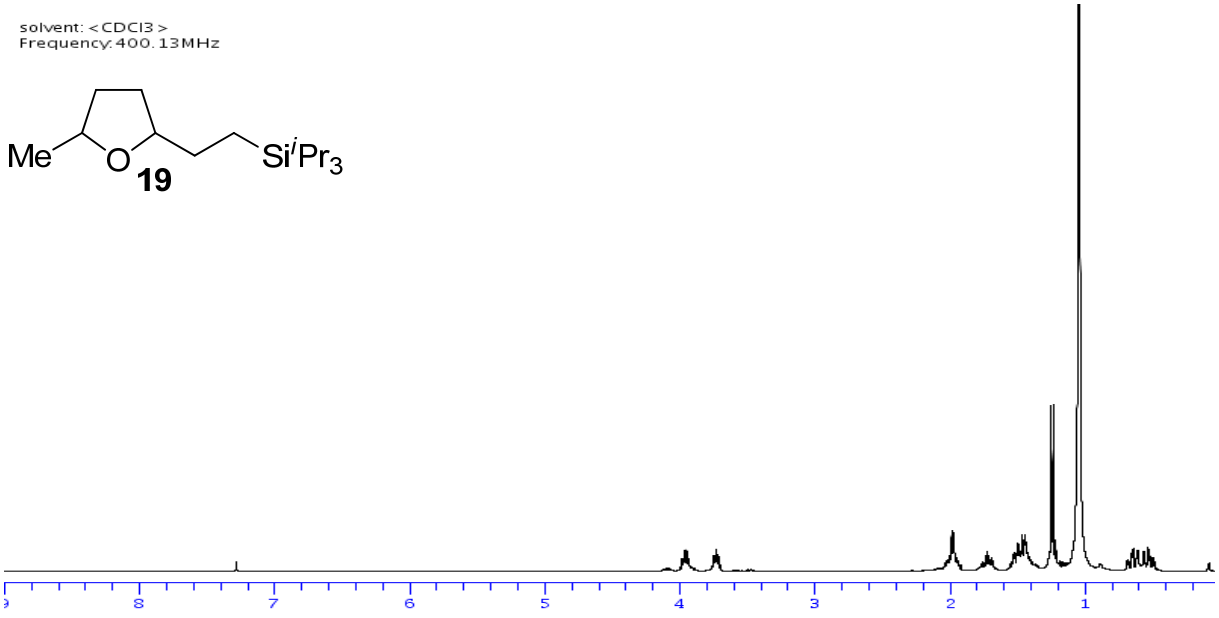
solvent: <CDCl3>
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Me
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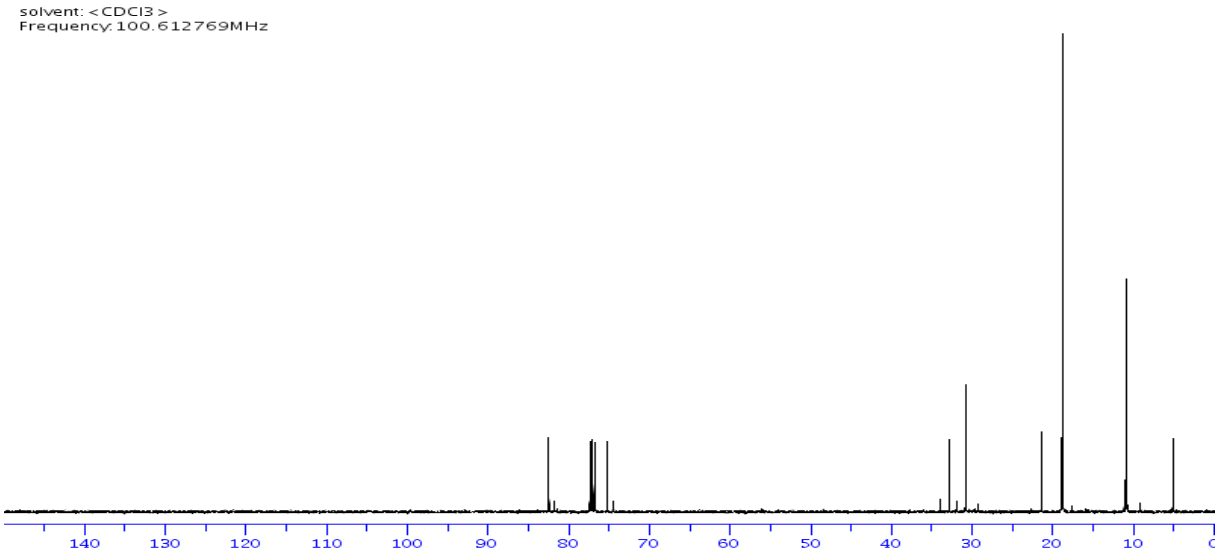
19
Si^{i}Pr$_3$
8
7
6
5
4
3
2
1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80
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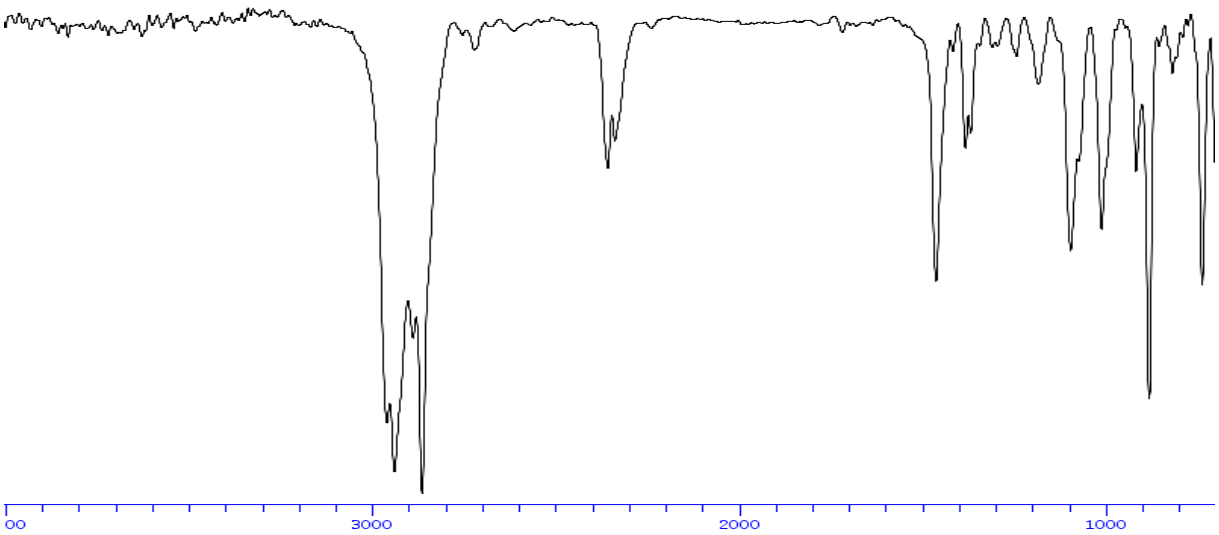
60
50
40
30
20
10


3000
2000
1000